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ARTICLE II. COMMERCIAL FERTILIZERS.

I. INTRODUCTION.

Agricultural chemistry, working hand in hand with agricultural practice, has demonstrated that of the dozen or more elementary substances or compounds which plants may take from the soil in their growth, there are but three of which ordinary soils are likely ever to show any deficiency. These three are nitrogen, phosphoric acid and potash.

Nitrogen, it is true, comes ultimately from the atmosphere, of which it constitutes about four-fifths; but in the form in which it exists in the atmosphere it is useless to vegetation. It must first enter the soil, and be there combined with other substances, before it can become available to plants. Ordinary soils contain large quantities of nitrogen, which exists in the humus of the soil—a term applied to the partially decayed roots, leaves and other organic matters found in all soils—but in such combinations that it is of little or no service to vegetation until changed into other combinations by the further decay of this humus.

The fertility of black soils in general is partly due to their large supply of humus, it being humus that gives them their dark color. When this humus has been formed from the decay of plants that naturally grow upon comparatively dry land, it readily enters into such combinations as are required by cultivated plants; but when formed from aquatic or semi-aquatic plants, in a soil constantly saturated with water, its nitrogen may be so firmly held that the ordinary methods of cultivation fail to bring it within reach of the farmer's crops, and their growth is pale and sickly. Illustrations of this may be found in drained muck beds and similar soils, and the fact that these soils may be rendered productive by the application of stable manure is explained by the supposition that such manure sets up a fermentation in the soil, which causes its nitrogen to be released from its fixed combinations. And it has been demonstrated that in ordinary soils the nitrogen of the humus is released by a process similar to fermentation, one which takes place only during warm weather and in the presence of moisture.

The phosphoric acid and potash of the soil are derived from the rocks, by the gradual weathering or grinding up of which all soils have been formed. Some of these rocks have contained phosphoric acid in combination; others have contained potash. But the phosphoric acid and potash of the soil, like the nitrogen, exist, not in such condition that plants may make immediate use of them, but in fixed combinations, from which they are liberated, little by little, from season to season, as they may be required by each season's growth of vegetation. The wisdom of this arrangement is apparent when we reflect upon the consequence that would follow were all these elements to exist in the forms in which we are best acquainted with them—as in the potash of wood ashes, for instance—which would be quickly washed out of the soil and carried to the ocean by rain and river.

But it has sometimes happened that the rocks from which a soil has been formed were deficient in phosphoric acid or potash, just as a hillside upon which no vegetation has grown must evidently be deficient in humus-nitrogen; or it may happen that the potash and phosphoric acid are held in certain rocks in such firmly fixed combination that they are not liberated with sufficient rapidity to feed a vigorous crop—like the nitrogen of the muck bed.

From this brief consideration of the origin of soils we may understand that some soils may be deficient in nitrogen, others in phosphoric acid, others in potash; while in still others there may be a lack of two or all three of these substances, or—what amounts to the same thing—too slow an annual liberation for profitable crop production. Another important fact has been demonstrated in this connection, and that is, that if a single one of the substances required by the plant be entirely absent from the soil no growth can take place until that substance be supplied, no matter how rich the soil may be in the other essential substances. It has also been demonstrated that certain crops take from the soil the three substances named in certain definite proportions, and that the ability of the soil to support the crop, or the value of a fertilizer, is gauged by the quantity of that ingredient which it may contain in smallest amount, relative to the needs of the plant. In other words, if the soil, in order to grow a good crop of wheat, needs a fertilizer containing forty pounds each of nitrogen, phosphoric acid and potash per acre, but if we attempt to economize by leaving out half the nitrogen, we shall lose half the phosphoric acid and potash applied.

It has been supposed that chemical analysis would furnish a guide to the economical manuring of the soil, and that by knowing the chemical composition of any particular soil, and also of the crop which it was desired to grow upon that soil, we might be enabled at once to adjust our manuring to the relative needs of soil and crop. Upon this point I can not do better than to quote the following paragraphs from a recent bulletin of the North Carolina Experiment Station, written by Dr. H. B. Battle, Director of the Station and State Chemist:

> The fallacy of the reasoning lies in the fact that a chemical examination of the soil, while it does give the total quantity of its constituents, does not give the quantity available to the plant, such as can be utilized by the plant. This fact is all-important, for there may be plant food in abundance in the soil, yet in such a form that it is impossible for the plant to derive any benefit from its presence though it may lie in intimate contact with its numerous roots. Many of our ordinary feldspathic rocks contain in every 100 lbs. as many as 10 lbs. of potash. Yet these 10 lbs.—almost equivalent to 100 lbs. of Kainit—are in such an insoluble, unavailable form, that they are absolutely unserviceable as plant food, unless by some process of disintegration and decomposition, they may become changed to a form which the plant can utilize.
>
> The thorough chemical examination will give the quantity of potash present, and likewise the quantity of the other chemical elements, but the science of chemistry or plant physiology has not yet devised an exact method for determining the proportion of these constituents, which is available to the needs of the plant, and which can be used by it in its growth. Chemistry is constantly advancing; new theories are brought forward, new methods are studied. It may not be a very distant day before reliable data will be obtained, which will give through chemical investigation, the exact proportion of the total mineral elements present, which will be available to plant growth.
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> But does a chemical analysis of the soil, no matter with what exactness it is carried out, show with sufficient accuracy the contents of the soil? Can we depend on its results to show with definiteness what fertilizer should be applied to the soil to render it more productive? For this distinct purpose the chemical analysis, always so delicate and accurate, is inadequate. A cubic foot of our average upland soil (from results obtained at the station in the past) weighs 110 lbs. An acre of this soil, 9 inches deep, weighs 2,835,062 lbs., or a fraction over 1,417 tons. Nine inches is taken as an average depth reached by plant roots; with many plants the tap root grows much lower than this. The ordinary application of ammoniated fertilizer is 200 to 300 lbs. to the acre. If this application of 300 lbs. is thoroughly mixed with the soil to the depth of nine inches and an average sample obtained, then by no chemical means, no matter how delicate, can this ammoniated fertilizer be detected; and yet this application changes the yield from an unproductive to a productive one, and draws the line between success and failure.

Realizing this failure of the laboratory to settle the questions at issue, investigators have turned their attention to field experiments, in which the attempt is made to ascertain the want of the soil by giving to it certain of the necessary elements of soil fertility and withholding others.

But this work is attended with great difficulties. So great is the variation in natural fertility in soils, that appear to the eye to be identical in composition, that the results of field experimentation are liable to be even more misleading than those of the laboratory. Take any single acre of ground for illustration · An open glade in the original forest may have permitted the wind to sweep away its winter-coverlet of leaves, and they may have lodged in a thicket of underbrush adjoining, carrying stores of potash and phosphoric acid with them. Such a glade may have been for centuries the pasturing ground of deer. It would then accumulate nitrogen, but would lose potash and phosphoric acid through an additional channel; while the thicket would accumulate these in excess of nitrogen. The growth of a surface rooting tree in one spot may have drawn heavily upon the adjacent surface soil for supplies of potash; that of a tree with a deep tap root in another may have drawn its support largely from deeper layers of the soil, and also have opened a way for drainage. A slight depression in the soil here may have received added fertility in the wash from a slight elevation there, and he who has studied the soil carefully, especially when its levels are shown by the melting of snow when the ground is frozen, will have detected irregularities of level unsuspected by the casual observer.

These are a few of the sources of error against which the field experimenter must guard his work, and they are sufficient explanation of the contradictory results that are so often attained in this form of investigation. Indeed, so difficult is it to reach absolute certainty in this work that some investigators have been disposed to condemn field experimentation as wholly unreliable. But the great field experiments of Sir John B. Lawes have demonstrated, that when this work has been conducted over a sufficient length of time, and on soil the natural inequalities of which have been removed, so far as is possible, by thorough drainage and careful tillage, it may yield results of incomputable value.

Believing the study of the problems connected with the maintenance of soil fertility to be of paramount importance to the farmers of Ohio, an elaborate series of experiments has been instituted at the Experiment Station, the object of which is to compare the effect of various fertilizers and fertilizing compounds upon the leading crops of the State.

The plan of these experiments is as follows: Five sections have been laid out and subdivided into plots of one-tenth and one-twentieth acre each. Four of these sections are to be devoted to continuous cropping with corn, oats, wheat and potatoes, respectively, and the fifth is to be cultivated in rotative cropping. The general arrangement of these sections is shown in diagram 1. In diagram 2 is shown the plan under which each of the sections devoted to corn, oats and wheat is subdivided into plots and fertilized. Each plot is 16 feet wide by 272$\frac{1}{3}$ feet long, and contains one-tenth acre. The plots are separated by alley-ways two feet wide. Under every alternate alley-way a tile drain is laid, thus giving a drain on one side or the other of each plot. Every third plot is left unfertilized, so that each fertilized plot has an unfertilized one on one side or the other, for comparison. In addition to the under-drains, the plots are being plowed into low ridges, leaving furrows in the alley-ways, in order that surface washing may not convey fertility from one plot to another, and that water may not stand on any portion of the land under experiment.

DIAGRAM I.—FIELD EXPERIMENTS WITH FERTILIZERS.

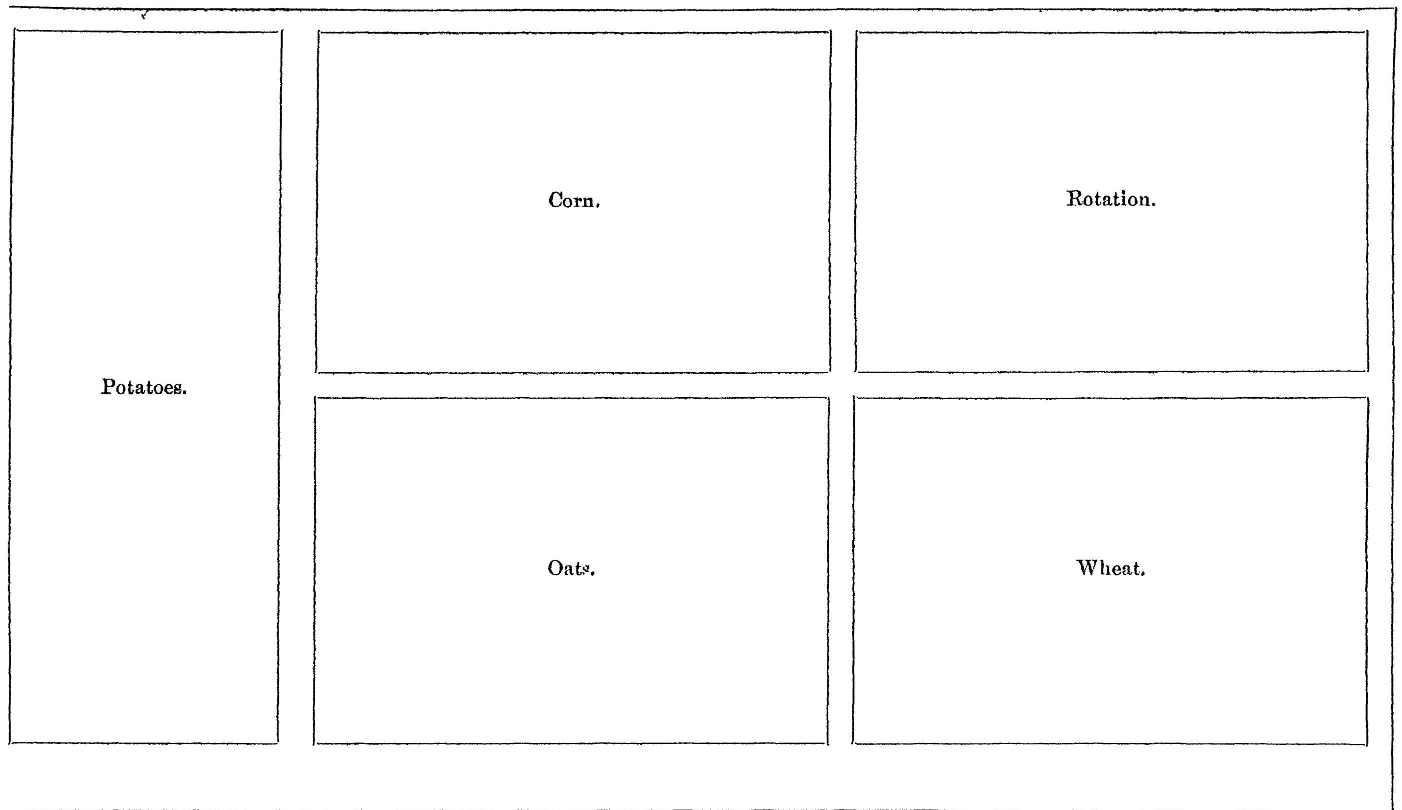


DIAGRAM II.—FIELD EXPERIMENTS WITH FERTILIZERS.

1. Unfertilized.
2. Superphosphate (dissolved bone-black).
3. Potash (muriate).
4. Unfertilized.
5. Nitrate of Soda.
6. Superphosphate and nitrate
7. Unfertilized.
8. Superphosphate and potash.
9. Potash and nitrate.
10. Unfertilized.
11. Superphosphate, potash and nitrate.
12. Superphosphate, potash and nitrate.
13. Unfertilized.
14. Superphosphate, potash and nitrate.
15. Superphosphate, potash and ammonia.
16. Unfertilized.
17. Nitrate, potash and rock phosphate.
18. Nitrate, potash and slag phosphate.
19. Unfertilized.
20. Barn-yard manure.
21. Linseed oil-meal.
22. Unfertilized.

On the first eleven plots of the sections devoted to corn, oats and wheat, the three most essential elements of fertility, phosphoric acid, potash and nitrogen, are used, first singly, then in pairs, and lastly in combination of all, the object being to ascertain whether either of them may be omitted from a fertilizer for this soil.

On plot 12, nitrogen is used in double the quantity, and on plot 14 in three times the quantity used on plot 11, the object being to ascertain the most effective proportion of nitrogen to phosphoric acid and potash.

On plot 15 sulphate of ammonia is used as the source of nitrogen, in order to contrast ammonia-nitrogen with that of nitrates.

On plot 17, South Carolina phosphatic rock is used as the source of phosphoric acid, instead of dissolved bone-black; and on plot 18, the phosphatic fertilizer now made by grinding the slag resulting from steel manufacture by the Thomas-Gilchrist process is used. (It is intended to apply the same quantity of phosphoric acid in these materials as is contained in the 320 pounds dissolved bone-black used; but, owing to an error in computations, this was not accomplished in the experiments of 1889.)

On plot 20 it is intended to use barn yard manure containing approximately the same quantity of nitrogen as that used on plot 14, and on plot 21 it is proposed to apply a similar quantity of nitrogen in linseed oil-meal. By reference to table 1, which shows the distribution of the fertilizers used, with the quantity of nitrogen, phosphoric acid and potash contained in the amount allotted to each plot, it will be seen that the application of oil-meal contains an excess of nitrogen. For 1888 and 1889 this application was fixed at 1800 pounds, in order to make the work comparable with similar work done at Rothamsted, but it is probable that the experiment will be more satisfactory if the quantity be reduced to the point indicated.

The changes in the apportionment of nitrate of soda to plots 5, 6, 9, 11, etc., have been made to bring the work into conformity with plans adopted by a convention of field experimenters, held at Washington, D. C., March 5 and 6, 1889.

COMMERCIAL FERTILIZERS—TABLE I—QUANTITY AND COST PER ACRE.

Plot No.	Fertilizers.	Quantity.	Essential ingredients.			Cost.
			Nitrogen.	Phos. Acid	Potash.	
		Pounds.	Pounds.	Pounds.	Pounds.	
1	Unfertilized	....	....	....	....	....
2	Superphosphate[1]	320		50		$4 30
3	Muriate of Potash	160			80	3 60
4	Unfertilized	....	....	....	....	....
5	Nitrate of Soda	160[2]	25[2]			3 80
6	Nitrate of Soda Superphosphate	160[2] 320	25	50		8 10
7	Unfertilized	....	....	....	....	....
8	Superphosphate Muriate of Potash	320 160		50	80	7 90
9	Nitrate of Soda Muriate of Potash	160[2] 160	25[2]		80	7 40
10	Unfertilized	....	....	....	....	....
11	Superphosphate Muriate of Potash Nitrate of Soda	320 160 160[2]	25[2]	50	80	11 70
12	Superphosphate Muriate of Potash Nitrate of Soda	320 160 320	50	50	80	15 50
13	Unfertilized	....	....	....	....	....
14	Superphosphate Muriate of Potash Nitrate of Soda	320 160 480[3]	75[3]	50	80	19 30
15	Superphosphate Muriate of Potash Sulphate of Ammonia	320 160 120	25	50	80	12 10
16	Unfertilized	....	....	....	....	....
17	Dissolved S. C. Rock Muriate of Potash Nitrate of Soda	300 160 160[2]	25[2]	45	80	10 40
18	Thomas Slag (ground) Muriate of Potash Nitrate of Soda	400 160 160[2]	25[2]	78	80	10 60
19	Unfertilized	....	....	....	....	....
20	Barnyard manure	8 tons.	75	25	50	....
21	Linseed oil meal	1,800	90	38	25	18 00
22	Unfertilized	....	....	....	....	....

[1] Dissolved bone black.
[2] 480 and 75 pounds in 1888.
[3] 160 and 25 pounds in 1888.

The land on which this experiment is being made lies in the valley of the Olentangy, one of the largest branches of the Scioto. The rock underlying the soil is Huron shale, which, judging from diggings made in the neighbor ood, will be found at an average depth of 15 to 20 feet. On this rocky floor, through the combined action of drift and alluvial agencies, the materials have been deposited from which the soil has been derived. These materials are of various origin, consisting of sand, gravel, boulders and clay. The gravel is chiefly limestone, but contains a considerable proportion of rounded fragments of black shale, the boulders are chiefly the granitic rocks that constantly accompany the drift in Ohio, together with an occasional limestone; the clay is the ordinary boulder-clay of this drift, with a considerable admixture of fragments of shale. This frequent occurrence of shale in the soil and gravel shows that the Huron shale, whose line of outcrop follows approximately the line of glacial erosion through this part of the State, has been one of the chief sources of the soil of this field.

Under the section devoted to oats and corn, gravel is found at a depth of three to five feet, and this portion of the field would not hav required under-drainage in ordinary farm practice. There were portions, however, in which the drainage was less perfect than in others, and it was thought best to drain the whole, in order to make the conditions, both of drainage and aeration, as uniform as possible. The gravel is not found under the sections devoted to wheat and rotation; on the contrary, there exists here a very retentive subsoil, the "boulder clay" of the drift, and in wet seasons crops have suffered much from lack of drainage. The Huron shale weathers quickly into a heavy clay, which has been found to be rich in potash, and appreciable quantities of gypsum are found in the clay, due probably to a combination of pyrites and lime, both of which are found both in the shale and in the gravel of the drift. It would be expected that a soil of such origin would not be deficient in available po ash, and such seems to be the case with this soil. In fact, it is a soil of great natural fertility. When properly drained and well tilled, it yields abundant crops, and for this reason a test of fertilizers must be less satisfactory here than it might be on a soil of a different nature.

There are, however, two questions which we may ask this soil, for the answering of one of which, at least, its natural fertility will be an advantage, and for the other no disadvantage. These are:

1. How can we most economically maintain the fertility of our soil?
2. To what limit may we profitably increase the fertility of a good oil?

It was with a full realization of the character of this soil and the consequent difficulty of drawing from it an answer to all the questions on which it would be desirable to have information, that this work was undertaken, and therefore, simultaneously with the starting of this series of experiments on this soil, preparations were begun to institute similar investigations on other and less fertile soils in different parts of the State. The progress of this work will be reported further on

Of the previous treatment of this field we have no record, prior to 1877. Since that date the cropping has been as follows 1877, wheat; 1878, 1879, 1880, timothy; 1881, 1882, corn; 1883, 1884, wheat; 1885, 1886, 1887, clover. It was dressed with barnyard manure in the spring of 1881, the manure being plowed under, it was top dressed in the fall of 1883 for the wheat crop following. In the spring of 1888 the field was drained and corn was planted on the section devoted to that crop. On the section devoted to oats, millet was grown in 1888, it being too late to sow oats after the drainage was completed. The section devoted to wheat lay idle until fall. A considerable growth of volunteer clover sprang up, which was plowed under in preparing the land for wheat.

COMMERCIAL FERTILIZERS ON CORN.

FIELD TESTS AT THE STATION.

Table II gives the rates of yield for 1889 of the plots devoted to corn, the yields being calculated to full stand.* In 1888, the crop contained more than an ordinary proportion of water when harvested, owing to the extremely wet season. For this reason, samples containing 100 pounds of ears were taken from each plot and placed in open barrels, so arranged that the air could have free access, and allowed to stand until January, when they were weighed again A table showing the shrinkage in weight for part of these samples is given in the Annual Report of this Station for 1888, page 94. Owing to a mistake in weighing, the shrinkage of samples from plots 12 to 22 inclusive, was not determined; but the weights given show that there was no connection between the variations in weight and the variations in treatment of the plots. The average shrinkage was about 17 per cent. of the original weight—or approximately one-sixth.

In harvesting the crop of 1889, similar samples of 100 pounds each were taken from the plots, which were dried until January, and then weighed again as before. The shrinkage in this case was much smaller than before, averaging about 6 per cent. In this test, as in the previous one, no connection whatever is found between the variations in shrinkage in drying and in treatment of the plots. It is believed, however, that a more satisfactory comparison of the results of different harvests can be made if

*For data from which the computations are made see Table XIII.

these results are reduced to January condition, and therefore such reduction has been made in tabulating the results in Table II, the yields there reported being obtained by reducing the yields as weighed in the field, by the percentages lost in drying, and which are given in the table.

Table II therefore includes:

(1.) The yield of grain per acre for 1889, as weighed when harvested, in November;

(2.) The percentage loss of the grain in drying until January, as determined by drying 100-pound samples;

(3.) The yield, as determined by the January weights, and

(4.) The apparent increase due to the fertilizers.

In computing the increase of the fertilized plots, in this and subsequent tables, each fertilized plot is compared with the unfertilized plots between which it lies, on the following plan: Suppose that plots 1 and 4, unfertilized, have yielded 40 bushels and 55 bushels respectively, it is assumed that plot 2 would have produced 45 bushels, and plot 3, 50 bushels without any fertilizer. In calculating the probable unassisted yield of any fertilized plot, therefore, the yield of the unfertilized plot nearest it has been multiplied by two, that of the plot farthest away added to the product, and the total sum divided by three.

Of course, this is "guess work," but it seems more logical to assume that the variations in fertility change uniformly from plot to plot, than that they take place abruptly, as must be done when simple averages only of distant unfertilized plots are taken as the standard with which to compare intervening plots.

A careful study of this table fails to discover that any marked influence has been exerted on the crop by any of the fertilizers. There are considerable variations, it is true, between the yields of some of the fertilized plots and the unfertilized ones adjoining; but these variations do not occur with sufficient regularity to justify the assumption that they are due to the fertilizers.

Even where it seems safest to assume that the fertilizers have increased the crop, as when plots 20 and 21 are compared with the unfertilized plots, 19 and 22, the increase shown is wholly inadequate to cover the cost of the manure or fertilizer.

COMMERCIAL FERTILIZERS—TABLE II.—EXPERIMENTS ON CORN AT THE STATION.

Yield per acre, corrected to full stand.—1 bushel=70 lbs. ears.

Plot No.	Fertilizers.	Yield as weighed in November.	Loss of weight in drying.	Yield as weighed in January.	Increase over unfertilized plots.
		Bushels.	*Percent.*	*Bushels.*	
1	Unfertilized	64.6	5½	61.0	....
2	Superphosphate (dissolved bone-black)	65.0	4½	62 1	0
3	Potash (muriate)	60.0	5½	56.7	0
4	Unfertilized	68.3	5	64.9	....
6	Nitrate of soda	67.7	7	63.0	1.0
5	Nitrate and superphosphate	68.9	5½	65.1	6.0
7	Unfertilized	59.3	5¼	56.2	....
8	Superphosphate and potash	63.7	6½	59.6	3.4
9	Nitrate and potash	67.6	7	62 9	6.7
10	Unfertilized	61.1	8	56.2	....
11	Superphosphate, potash and nitrate	71.1	5¼	67.4	8.5
12	Superphosphate, potash and nitrate	63 9	4	61 3	0
13	Unfertilized	67.7	5	64.3	....
14	Superphosphate, potash and nitrate	61.4	6½	57.4	0
15	Superphosphate, potash and ammonia	57.4	4½	54 8	0
16	Unfertilized	56.7	7¾	52.3	....
17	Rock phosphate, potash and nitrate	57.3	6	51.9	0
18	Slag phosphate, potash and nitrate	61.0	11½	54.0	1.5
19	Unfertilized	55.4	5	52.6	....
20	Barnyard manure	66.4	5½	62.8	8.0
21	Linseed oil meal	72 6	3	70.4	13.4
22	Unfertilized	61.3	3½	59.2	....
	Average of unfertilized plots	61.8	5½	58.3	

The average yield, as weighed in January, of the six plots receiving a complete mineral fertilizer, viz: Nos. 11, 12, 14, 15, 17, 18, was 66 bushels per acre for the two seasons; that of the four adjoining unfertilized plots, viz: Nos. 10, 13, 16, 19, was 64.4 bushels—an increase of a bushel and a half of corn for the fertilizer. The average decrease in yield of the six fertilized plots in 1889, as compared with 1888, was 16.5 bushels; that of the four unfertilized plots was 16.2 bushels. So far as these two seasons are concerned, therefore, the mineral fertilizers appear to have contributed nothing towards checking the diminution in yield, due to climatic and other causes. The average decrease in yield for all the plots was 17.1 bushels; for the plot receiving barnyard manure it was 15.5 bushels; and for the one receiving oil-meal it was 17.3 bushels.

In regard to this use of oil-meal as a fertilizer it may be well to explain that the object in view is to determine its incidental value as a fertilizer. Linseed oil-meal is a valuable feeding stuff, and careful experiments have shown that after it has performed its function as a feeding stuff, two-thirds of its value as a fertilizer may yet be recovered in the manure, if the manure be properly cared for. But we are shipping our oil-meal to Europe, and sending to South America for nitrate of soda, to Germany for potash salts, and to South Carolina for phosphatic rock, with which to compound our fertilizers.

CO-OPERATIVE TESTS BY FARMERS.

The plan of these tests is somewhat less elaborate than that of the tests conducted at the Station, no comparison being attempted between different quantities or kinds of nitrogen and phosphoric acid. Nitrate of soda is used in all cases at the rate of 160 pounds per acre, dissolved bone-black at the rate of 320 pounds, and muriate of potash at the rate of 160 pounds. Thirteen or more plots are used in these tests, arranged as below:

1. Unfertilized.
2. Superphosphate (dissolved bone-black).
3. Muriate of potash.
4. Unfertilized.
5. Nitrate soda.
6. Nitrate of soda and bone-black.
7. Unfertilized.
8. Superphosphate and potash.
9. Nitrate and potash.
10. Unfertilized.
11. Superphosphate, potash and nitrate.
12. Barnyard manure.
13. Unfertilized.
14. Land plaster.

FARM TEST IN COLUMBIANA COUNTY, BY H. Y. BENTLEY.

The first of these tests was located in Columbiana county, the experiment being commenced in 1888, and the report of the first season's test being given in the Annual Report of this Station for that year. In that report the location of the test is described as a high, "soap-stone" or slaty point, the soil being about ten feet of decomposed slate, resting upon slate rock, which gives natural drainage. The soil is quite loose, and always easily worked, but lacking in natural fertility.

COMMERCIAL FERTILIZERS—TABLE III.—EXPERIMENTS ON CORN IN COLUMBIANA COUNTY, BY H. Y. BENTLEY.

Yield per acre, corrected to full stand—1 bushel=70 lbs. ears.

Plot No.	Fertilizers.	Grain.	Increase.
		Bushels.	*Bushels.*
1	Unfertilized	53.5	....
2	Superphosphate (dissolved bone-black)	55.9	0.9
3	Potash (muriate)	56.3	0
4	Unfertilized	58.1	....
5	Nitrate of soda	58.4	0
6	Nitrate and superphosphate	62.6	0
7	Unfertilized	65.7	....
8	Superphosphate and potash	62.8	0
9	Nitrate and potash	67.2	3.8
10	Unfertilized	62.2	....
11	Superphosphate, potash and nitrate	66.0	5.3
12	Barnyard manure	74.0	14.7
13	Unfertilized	57.8	....
14	Common salt	60.0	2.2
	Average of unfertilized plots	59.5	....

Table III gives the principal results of this test for 1889. The yields of the several plots were much more uniform in 1889 than in 1888, but no satisfactory evidence can be gleaned from this table that any of the fertilizers used, except stable manure, were of any decided advantage to the crop.

The great excess of weight of the stalks in 1888 over 1889 was no doubt chiefly due to the excessively wet fall of 1888, in consequence of which the fodder contained much more water when weighed than it did in 1889. For the same reason, the average yield of grain in 1888 is exaggerated.

FARM TEST IN LICKING COUNTY, BY LEVI KNOWLTON.

Table IV gives the results of a test made by Mr. Levi Knowlton, of Utica, Licking county.

The soil is drift clay, lying over rocks of the Waverly formation, and bordered by hills of the same formation, from which its character has probably been modified.

The land was in timothy sod when plowed for this crop. It was plowed about the middle of April, eight inches deep, harrowed twice with disc harrow, once with spike harrow, "slabbed," and planted May 8, with hand rotary planter, four grains to hill, afterwards thinned to three; variety, Leaming. The fertilizers were distributed broadcast. The corn was cultivated four times.

COMMERCIAL FERTILIZERS—TABLE IV.—EXPERIMENTS ON CORN IN LICKING COUNTY, BY LEVI KNOWLTON.

Yield per acre, as weighed in the field—1 bushel=70 lbs. ears.

Plot No.	Fertilizers.	Grain.	Increase.
		Bushels.	*Bushels.*
1	Unfertilized	44.8	....
2	Superphosphate (dissolved bone-black)	58.6	6.4
3	Potash (muriate)	75.1	15.4
4	Unfertilized	67.1	....
5	Nitrate of soda	56.8	0
6	Nitrate and superphosphate	74.0	11.4
7	Unfertilized	60.3	....
8	Superphosphate and potash	59.7	0
9	Nitrate and potash	58.0	0
10	Unfertilized	60.0	....
11	Superphosphate, potash and nitrate	53.7	0
12	Barnyard manure	70.5	3.2
13	Unfertilized	67.4	....
14	Land plaster	58.3	0
15	Jarecki fish guano*	67.4	0
16	Homestead tobacco grower**	74.3	6.9
	Average of unfertilized plots	59.9	....

*500 lbs. per acre=nitrogen, 12 lbs.; phosphoric acid, 50 lbs.; potash, 15 lbs.

**300 lbs. per acre=nitrogen, 10 lbs.; phosphoric acid, 30 lbs.; potash, 10 lbs.

Apparently this soil, like that of the Station farm, is sufficiently fertile to produce good crops of corn without the addition of any fertilizer. The largest yield is shown by plot 3, receiving potash. Plots 6 and 16, however, the one receiving no potash and the other but a small quantity, show practically the same yield.

FARM TEST IN ASHTABULA COUNTY, BY GEO. H. BUNNELL.

Table V gives the yields obtained by Mr. George H. Bunnell, of Jefferson, Ashtabula county. Mr. Bunnell describes his soil as follows:

The rock under our soil is the "Erie Shale" and is from 10 to 25 feet below the surface. The experiment plat being near a large creek, the bed of which is shale, it is probable that the rock is not more than 10 feet from the surface. There is always a bed of blue clay before we get to the rock. In fact, this shale will turn to blue clay, and the clay to a good grass soil on exposure to the atmosphere, but the surface soil of the experiment plat is less tenacious and more of the nature of a drift deposit than the higher lands farther from the creek.

The land on which the experiment was made had been in pasture about 35 years, then cultivated about 20 years in a regular rotation of corn, oats, wheat and grass, the grass occupying the land until it required re-seeding. In this entire period it had had but one application of manure —"about five years ago, at the rate of about fifteen two-horse loads per acre. It was plowed and thoroughly pulverized May 20, planted May 22, with one-horse corn drill, in rows 4 feet apart and kernels dropped every 12 inches. The plots were four rows (16 feet) wide, and long enough to contain one-tenth acre each. A row of potatoes was planted between every two plots. It was cultivated four times, and hoed by hand twice." The fertilizers were applied, half broadcast and half in the hill.

COMMERCIAL FERTILIZERS—TABLE V.—EXPERIMENTS ON CORN IN ASHTABULA COUNTY, by GEO. H. BUNNELL.

Yield, per acre as weighed in the field—1 bushel=70 lbs. ears.

Plot No.	Fertilizers.	Grain.	Increase
		Bushels.	*Bushels.*
1	Unfertilized	31.6	....
2	Superphosphate (dissolved bone black)	51.3	19.6
3	Potash (muriate)	40.3	8.6
4	Unfertilized	31.8	....
5	Nitrate of soda	33.1	.0
8	Nitrate and superphosphate*	42.0	7.6
7	Unfertilized	35.7	....
6	Superphosphate and potash*	55.7	21.5
9	Nitrate and potash	35.6	2.8
10	Unfertilized	31.3	....
11	Superphosphate, potash and nitrate	46.4	15.9
12	Barnyard manure	48.6	18.8
13	Unfertilized	29.0	....
	Average of unfertilized plots	31.9	

*In this test these plots were transposed, nitrate and superphosphate being applied to plot 8, and superphosphate and potash to plot 6. The order is reversed in the table in order to correspond with the other tables.

In this experiment we get a very striking result. The average yield of the unfertilized plots is 31.9 bushels per acre, and that of the four plots receiving phosphoric acid is 48.8 bushels—an increase of nearly 17 bushels. It would seem, moreover, that this increase is due entirely to the phosphoric acid or to the combination of phosphoric acid with potash, and that nitrogen is not needed. But, as has been already pointed out, it is not safe to draw final conclusions from a single test.

Mr. Bunnell suggests the following explanation of the action of the fertilizers in this experiment:

> It will be seen in this test that phosphoric acid alone, and in combination with potash and also nitrogen, increased the yield very materially, while potash increased it in a considerably less degree, and nitrogen practically not at all; a result as surprising to me as to all those that consider nitrogen the most essential element in all manures. It is possible that this nitrogen, being in the form of nitric acid, washed below the reach of the corn roots (the fore part of the season being very wet), while if it had been in the form of ammonia the result might have been different; but a better explanation to me is that the available phosphoric acid had been continually lessened, in making bones for growing animals, in the series of years that this field was in pasture, while the nitrogen that had accumulated during this time, beyond the needs of the animals pasturing thereon, was not all exhausted by the subsequent use that the land was put to, namely: raising crops to be removed; consequently there was plenty of nitrogen in the soil, and it only needed the addition of phosphoric acid (as there seemed to be potash enough) to make a full crop.

It is probable that both causes suggested have operated to produce the result observed. As has already been shown, the exhaustion of any one of the essential elements of fertility will favor the accumulation of the others in the soil. It is a fact generally recognized that the grazing of growing animals does tend to the exhaustion of the phosphoric acid of the soil, and it would follow that the grain crops that have been occasionally grown upon this land would find the supply of phosphoric acid scanty, and would therefore be unable to utilize the extra amount of nitrogen and potash available. Some of the excess of nitrogen would be accumulated in the humus of the soil, formed from the decay of the roots of grass and grain crops, while much of it would be washed away by the rain.

Potash and phosphoric acid, however, are not so readily washed out of the soil, as nitrogen. Indeed, in ordinary clays they are held with great tenacity.

If this hypothesis be correct, the time may come when the soils of this region will no longer respond to phosphate alone, but will require nitrogen in addition before yielding a profitable return for the fertilizer. Indeed, it would seem as if the time had already come to some portions of this region, as the complaint is common that phosphates do not produce such increase of crops as they once did.

Corn, however, seems to be able to find nitrogen where wheat fails to do so, and this, after all, may be the sole cause of the uselessness of nitrogen in this experiment.

FARM TEST IN HURON COUNTY, BY W. B. HALL.

Table VI gives the results obtained by W. B. Hall, of Wakeman, Huron county. Mr. Hall describes his soil as a sandy loam, inclining to clay in places. The subsoil is the boulder clay of the drift, and the underlying rocks belong to the Berea Grit. The land was originally covered with very fine timber—oak, "poplar," rock-maple, black and white ash, beech and linden. For some years previous to 1883 it had been rented for money rent and the crops removed.

The field was plowed May 16, it was harrowed and the fertilizers sown broadcast, May 17, and was planted May 18. The season was very wet and cold, and the corn was slow to germinate. It was cultivated twice. The White Grub was very troublesome, causing an imperfect stand.

It will be seen that Mr. Hall's results are quite as decidedly in favor of phosphoric acid as are those of Mr. Bunnell. Potash seems to have increased the yield somewhat, judging by the yields of plots 3, 8 and 14; one of the functions of land plaster being to liberate potash from its combination in the soil; but nitrogen seems not to have been required

Hill or broadcast fertilizing. Attention is called to the fact that in Mr. Bunnel's experiment the fertilizers were applied half in the hill and half broadcast, and in Mr. Hall's, altogether broadcast. The results are practically identical.

In a large number of similar experiments made by the South Carolina Experiment Station during 1888, this point of applying fertilizers in the hill or broadcast received special attention, the test being duplicated on each of the three experiment farms of that Station. The conclusions reached by Director McBryde, in summing up the results of these tests, were that no difference whatever was observable from the different methods of applying the fertilizers.

During the years 1877–81, a large number of similar tests were made under direction of Prof. W. O Atwater, then director of the Connecticut Experiment Station. Prof Atwater summarizes the results as follows, in a special report issued by the National Department of Agriculture in 1883:

The testimony of the experiments is on the whole against applying in the hill or drill. The best results in the majority of cases came where the fertilizers were sown broadcast. Several of the very best were where the materials were scattered over a strip a couple of feet or so wide along the rows. Many of the worst results were where the fertilizers were put in the hill or drill. The nitrate of soda and potash salts thus applied often injured the crops, especially in dry weather.

Respecting the philosophy of this practice, Prof. Atwater says:

Experiments with concentrated fertilizers are often spoiled, just as crops are injured or lost through wrong application. Farmers are apt to think that the manure must be put close to the seed, or the plant will not get the benefit of it. This is wrong. It is not the just germinated plantlet that needs the manure, but the plant, from the time it is well started until its growth is done. We want, not only to give the crop a good start, but to help it out on the home stretch as well. The roots and their branching rootlets run out in all directions in search of food, and the fertilizers ought to be where as many of the rootlets as possible can get at them. If we distribute the fertilizers as well as we can, the water in the soil, aided by the chemical and physical forces that nature keeps in operation, will do the rest. In illustration of this remember how well barn-manure acts when applied as a top-dressing long before the seed is put in.

But if we concentrate the fertilizers in one place fewer roots well get them, and these may be injured by coming in contact with them or with their concentrated solutions in the soil. The roots will find their way to the manure and develop more where it lies, it is true, still we should not oblige them to huddle together in one place, but should rather encourage them to spread around, where, with the increased capacity the fertilizer gives them, they can get the more trom the soil. Roots join with other natural agents in rendering inert stores of plant food available.

COMMERCIAL FERTILIZERS—TABLE VI.—EXPERIMENTS ON CORN IN HURON COUNTY, BY W. B. HALL.

Yields per acre, corrected to full stand.—1 bushel =70 lbs.

Plot No.	Fertilizers.	Grain.	Increase.
		Bushels.	*Bushels.*
1	Unfertilized	12.6	....
2	Superphosphate (dissolved bone-black)	33.8	20.4
3	Potash (muriate)	19.7	5.4
4	Unfertilized	15.1	....
5	Nitrate of soda	18.6	0
6	Superphosphate and nitrate	33.5	9.7
7	Unfertilized	28.2	....
8	Superphosphate and potash	42.8	16.1
9	Nitrate and potash	33.6	8.3
10	Unfertilized	23.8	....
11	Superphosphate, potash and nitrate	33.3	11.5
12	Barn yard manure (12 tons)	37.7	18.0
13	Unfertilized	17.7	....
14	Land plaster	27.3	9.6
15	Wheat bran*	29.5	11.8
	Average of unfertilized plots	19.5	

*400 lbs per acre,=nitrogen, 9 lbs; phosphoric acid, 11 lbs, potash, 5 lbs.

FARM TEST IN HOLMES COUNTY, BY A. WOLGAMOT.

Mr. A. Wolgamot, of Millersburg, Holmes county, made the experiment reported in Table VII. Mr. Wolgamot describes his soil as thin and gravelly, containing a small admixture of clay, and underlaid with gray limestone. It was plowed in April, "turning under a nice growth of rye." The fertilizers were distributed broadcast May 13, stirred in with a cutaway harrow, and the corn was planted May 15. The season was cold and wet until July. The corn was cultivated four times, "but was planted two weeks late." The yields in this case were ascertained by measurement, and were reported in bushels of ears, which have been reduced to shelled bushels by dividing by 2.

Mr. Wolgamot explains that plot No. 4 was located on an old dead-furrow, and that the lime used on plot 15 had been exposed to the weather for several years. He states that the corn was exceptionally bright and sound where nitrate of soda was used, and it would seem that the combination of nitrate and superphosphate has increased the crop.

COMMERCIAL FERTILIZERS—TABLE VII.—EXPERIMENTS ON CORN IN HOLMES COUNTY, BY A. WOLGAMOT.

Yield per acre as measured in the field.—1 bushel = 70 lbs.

Plot No.	Fertilizers.	Grain.	Increase.
		Bushels.	*Bushels.*
1	Unfertilized	60	....
2	Superphosphate (dissolved bone-black)	65	10.0
3	Potash (muriate)	50	0
4	Unfertilized	45	....
5	Nitrate of soda	60	10.0
6	Superphosphate and nitrate	75	20.0
7	Unfertilized	60	....
8	Superphosphate and potash	75	15.0
9	Nitrate and potash	75	15.0
10	Unfertilized	60	....
11	Superphosphate, potash and nitrate	77½	19.0
12	Barn yard manure (20 tons)	80	23.0
13	Unfertilized	55	....
14	Land plaster	60	5.0
15	Air-slaked lime	30	0
	Average of unmanured plots	56	

FARM TEST IN MIAMI COUNTY, BY B. E. FURNAS.

This experiment was made by Mr. B. E. Furnas, on a "sugar-tree clay, with subsoil of gray clay and gravel," which had been in cultivation eighty years. The treatment during recent years is described as follows:

1884, clover, 20 loads horse-manure turned under.
1885, corn, sown to wheat.
1886, wheat, sown to clover, but no stand secured. Pastured.
1887, wheat, sown to clover, but no stand secured. Not pastured.
1888, corn, sown to clover, but no stand secured.
1889, corn, fertilizer experiment.

The White Grub is noted as injurious in 1888, and in 1889 it destroyed about one-third of the stand. The injury was quite evenly distributed throughout the entire series of plots, so that it has not materially affected the general results.

The fertilizers were applied May 11 to 13. The corn was cultivated four times and hoed once. The season was too wet until July. The corn was of the "Clarage" variety. The first ripe corn was found September 5, on plot No. 11; next, September 7, No. 12; next, September 11, Nos. 8 and 9.

In this test, all the fertilizing elements seem to have increased the crop, whether used singly or in combination. The greatest increase is found on plot 11, receiving the complete fertilizer, where it amounts to nearly 30 bushels of shelled corn per acre over the average of the unfertilized plots. The details are given in Table VIII.

The results of this experiment are remarkably uniform. The average yield of the unfertilized plots was, avoiding fractions, 43 bushels per acre; that of the plots receiving a single fertilizing element, 50 bushels; that of the plots receiving two elements, 60 bushels, and that of the one receiving the three, 73 bushels—an increase of 7, 17, and 30 bushels respectively. But even with this large increase, the complete fertilizer has failed to pay its cost, with corn at 33⅓ cents a bushel, while the partial fertilizers have been used with still greater loss.

By reference to Table XII it will be seen that great care was taken in working out all the details of the experiment.

COMMERCIAL FERTILIZERS—TABLE VIII.—EXPERIMENTS ON CORN IN MIAMI COUNTY, BY B. E. FURNAS.

Yields per acre, corrected to full stand. 1 bushel=70 lbs. ears.

Plot. No.	Fertilizers.	Grain.	Increase.
		Bushels.	*Bushels.*
1	Unfertilized	40.0	....
2	Superphosphate (dissolved bone-black)	49.7	9.4
3	Potash (muriate)	48.1	7.5
4	Unfertilized	40.9	....
5	Nitrate of soda	52.0	9.5
6	Superphosphate and nitrate	58.9	14.7
7	Unfertilized	45.8	....
8	Superphosphate and potash	60.3	15.1
9	Nitrate and potash	60.1	15.5
10	Unfertilized	44.0	....
11	Superphosphate, potash and nitrate	73.5	29.6
12	Barnyard manure	52.2	8.4
13	Land plaster	48.5	4.7
14	Unfertilized	43.7	....
15	Unfertilized	31.8	....
	Average of unfertilized plots	42.9	....

FARM TEST IN BUTLER COUNTY, BY B. H. BROWN.

This experiment was made by Mr. B. H. Brown, of the Oxford Farmers' Club, Oxford, Butler county. The soil is a stiff clay, of drift origin, but the line of glacial erosion here lies for some distance immediately over the Cincinnati limestone, and this formation has therefore contributed largely to the making of the soil.

Mr. Brown writes·

"The experiment was made on a piece of the thinnest land on my farm. The soil is a stiff clay. that is a little wet and would be greatly benefited by underdrainage. It was in wheat in 1888, and sown to Alsike clover. It was plowed May 21 and planted on the 23d, drilling the corn 16 inches in the row, rows 3½ feet apart, on carefully measured tenth-acre plots, with five feet spaces between the plots. The stand was good, and I think, even all over. On the manure plot I hauled two good loads of fresh, horse-stable manure, the horses having been bedded with sawdust. This was evenly scattered, as also were the other fertilizers, and all were well harrowed in before the corn was planted.

"During the season plots 3, 6, 8, 11 and 12 were much the best, and withstood the ravages of the white grub. When the corn was cut, on September 20, there was scarcely a stalk fallen on plots 3, 8, 11 and 12, while on the unfertilized plots at least one-third was flat on the ground, and on the others quite a per cent was down.

"The experiment has been quite interesting to me, and has convinced me that by high cultivation and high fertilizing we can overcome the ravages of the white grub."

It will be seen that in this test phosphoric acid and potash, and especially potash, seem to have been the most effective in increasing the crop. The yields are given in table IX.

COMMERCIAL FERTILIZERS—TABLE IX.—EXPERIMENTS ON CORN IN BUTLER COUNTY, BY B. H. BROWN.

Yields per acre as weighed in the field. 1 bushel=70 lbs. ears.

Plot No.	Fertilizers.	Grain.	Increase.
		Bushels.	*Bushels.*
1	Unfertilized	18.3	....
2	Superphosphate (dissolved bone-black)	35.9	15.1
3	Potash (muriate)	41.7	18.3
4	Unfertilized	25.9	....
5	Nitrate of soda	26 7	0.2
6	Nitrate and superphosphate	35.7	8.6
7	Unfertilized	27.7	....
8	Superphosphate and potash	49.9	23.7
9	Nitrate and potash	37.9	13.1
10	Unfertilized	23.3	....
11	Superphosphate, potash and nitrate	48.0	22.7
12	Barnyard manure, 20 tons	67.4	40.0
13	Unfertilized	29.4	....
14	Land plaster	33.3	3.9
	Average of unfertilized plots	24.9	....

TEST BY MATTHEW SWAN, OF COLUMBIANA COUNTY.

In addition to the tests above described, the following simple experiment was made at the suggestion of the Station by Mr. Matthew Swan, of Alliance, Ohio. Mr. Swan's farm is in the northwestern part of Columbiana county, and the soil is probably of drift origin.

The object in view in this experiment was to learn the effect of increasing the ratio of nitrogen to phosphoric acid in a fertilizer for corn. The distribution of fertilizers and yield per acre in bushels of 70 pounds were as follows:

Plot	1.	Acidulated bone, 200 pounds	73½
"	2.	Nitrate of soda, 200 pounds	78½
"	3.	Pelican bone, 200 pounds	69½
"	4.	Pelican bone, 100 pounds; nitrate of soda, 100 pounds	79½

The differences here are not beyond the limits of possible variation in the soil of the different plots; but they indicate that the ratio of nitrogen may be increased with advantage.

YIELDS OF STALKS.

The weighing of corn-stalks, in field experiments, is more troublesome and uncertain than that of the grain, owing to their greater bulk and greater liability to be affected by differences in drying out or by rain. In table X are given the weights of stalks, as reported by the several experimenters. These weights are corrected to full stand in the experiments made at the Station and in Columbiana, Huron and Miami counties, and as taken in the field in the cases of the Licking and Butler county experiments. In the Ashtabula and Holmes county experiments the weights were not taken.

By comparing table X with table XI, it will be seen that in general the fodder weights are in harmony with those of the weights of grain.

COMMERCIAL FERTILIZERS—TABLE X.—EXPERIMENTS ON CORN.

Weights of stalks and increase on fertilized plots.—Pounds per acre.

Plot No.	Fertilizers.	County and experimenter.						Average.	Increase.
		Franklin—Station.	Columbiana—Bentley.	Licking—Knowlton.	Huron—Hall.	Miami—Furnas.	Butler—Brown.		
1	Unfertilized..........................	3,472	2,797	2,720	1,429	1,520	1,320	2,210	....
2	Superphosphate (dissolved bone-black)....	3,276	2,778	3,000	2,270	2,165	2,690	2,696	338
3	Potash (muriate).......................	3,390	3,001	3,560	2,000	2,090	2,700	2,790	281
4	Unfertilized...	3,564	2,987	4,160	1,536	1,856	1,850	2,659	....
5	Nitrate of soda..................................	3,788	3,030	3,320	1,531	2,234	2,000	2,650	....
6	Nitrate and superphosphate........	3,604	3,167	3,920	2,212	2,576	2,650	3,021	285
7	Unfertilized.......	3,441	3,280	3,480	2,342	2,006	2,100	2,775	....
8	Superphosphate and potash	3,762	3,502	4,200	2,870	2,620	3,400	3,392	620
9	Nitrate and potash..............................	4,104	3,549	3,520	2,808	2,679	2,550	3,202	433
10	Unfertilized..........	3,774	3,188	3,920	1,997	1,966	1,750	2,766	....
11	Superphosphate, potash and nitrate........	3,488	3,346	3,160	2,198	3,354	3,370	3,153	453
12	Barnyard manure.	3,509	3,757	3,360	2,171	2,704	4,680	3,363	729
13	Unfertilized.................	3,103	3,032	3,960	1,404	1,892	2,020	2,568	....

COMMERCIAL FERTILIZERS—TABLE XI.—Summary of Field Experiments on Corn.

Increase apparently due to fertilizers.—Bushels per acre.

Plot No.	Fertilizers.	Cost of Fertilizers per acre.	County and experimenter.								Average.
			Franklin—Station.	Columbi'a—Bentley.	Licking—Knowlton.	Asht'b'la—Bunnell.	Huron—Hall.	Holmes—Wolgamot.	Miami—Furnas.	Butler—Brown.	
1	Unfertilized										
2	Superphosphate, (dis. bone-blk)	$4 30	0.0	0.9	6.4	19.6	20.4	10.0	9.4	15.1	10.5
3	Potash, (muriate)	3 60	0.0	0.0	15.4	8.6	5.4	0.0	7.5	18.3	6.3
4	Unfertilized										
5	Nitrate of soda	3 80	1.0	0.0	0.0	0 0	0.0	10.0	9.5	0.2	1.6
6	Nitrate and superphosphate	8 10	6.0	0.0	11.4	7.6	9.7	20.0	14.7	8.6	9.8
7	Unfertilized										
8	Superphosphate and potash	7 90	3.4	0.0	0.0	21.5	16.1	15.0	15.1	23.7	11.6
9	Nitrate and potash	7 40	6.7	3.8	0.0	2.8	8.3	15.0	15.5	13.1	8.0
10	Unfertilized										
11	Superphos., potash and nitrate	11 70	8.5	5.3	0.0	15.9	11 5	19.0	29 6	22.7	13.2
12	Barnyard manure[1]		9.0	14.7	3.2	18.8	18.0	23.0	8.4	40.0	16.7
13	Unfertilized[2]										

[1] Plot 20, Station.

[2] Plots 19 and 22, Station; Plot 14, Furnas.

SUMMARY.

In table XI are collected the figures representing the apparent increase in yield of grain, due to the fertilizers in the several experiments of 1889. In the Station's experiments, the yields of the first eleven plots indicate that nitrogen has had a favorable, though small effect on the crop. The experiments in Columbiana and Licking counties give no decisive results. In the other five tests, however, the evidence is conclusive that the fertilizers have had a marked effect upon the crop. In the experiments of 1888, nitrogen seemed to have a marked effect in the Columbiana county test.

The results of the Ashtabula county and Huron county tests are strikingly uniform. These tests are located nearly 100 miles apart, but both agree in showing that on those soils and for this season, phosphoric acid was the essential element in a fertilizer for corn, with potash next in importance, while nitrogen was not needed at all. It would even seem that the addition of nitrogen had diminished the effect of the superphosphate, as shown in plots 6 and 11; but it is more probable that the lower yield of these plots is due to variations in the natural fertility of the soil.

In the Butler county test, located in the opposite corner of the State from the one in Ashtabula, and nearly 250 miles to the south-west, nitrogen seems to be as little required for the development of the corn plant as in the more northerly region; but in this test potash seems to play the leading part, with phosphoric acid second in importance.

Holmes and Miami counties lie in the middle belt of the State, but about 100 miles apart. In the tests in these counties we have again a series of as striking coincidences in the results as those found in the Ashtabula and Huron county tests; but here nitrogen appears to have been equally efficacious with phosphoric acid in increasing the yield, whether used alone or in combination, and potash has held about the same rank as in the northern counties.

PROFIT AND LOSS.

With corn at 33⅓ cents a bushel, dissolved bone-black has apparently been used alone with profit in the tests in Ashtabula, Huron and Butler counties.

Muriate of potash has been used alone with profit only in the Butler county test.

The superphosphate and potash have not been profitably combined in any case, but have paid cost, or nearly so, in the Ashtabula and Butler county tests.

Nitrate of soda has not paid its cost in any case, whether used alone or in combination with superphosphate and potash, one or both.

CONCLUSIONS.

The conclusions indicated by the foregoing experiments are these:

(1.) *On soils capable of producing fifty bushels of shelled corn per acre with good drainage and tillage, no artificial fertilizer or combination of such fertilizers is likely to produce sufficient increase of crop to pay the cost of the fertilizer in the crop to which it is applied, at present prices of corn and fertilizing materials, respectively.*

(2.) *On soils that are decidedly deficient in natural fertility, phosphoric acid may sometimes be used with profit in fertilizing for corn, and potash and nitrogen may be so used in rare instances, and this whether these substances be used separately or in combination.*

It is true that these conclusions are based upon the experiment of a single season only, and therefore they must be held subject to modification or reversal by more extended experience. It is probable, however, that such experience will tend rather towards confirming than reversing them.

In 1877 Prof. W. O. Atwater, then Director of the Connecticut Agricultural Experiment Station, instituted a series of experiments on the same plan as those described in this bulletin, which were made not only in Connecticut but also in several other states, and were continued for several years. The results of this work are summarized in a report issued by the National Department of Agriculture in 1883. Respecting the effect of the various fertilizer constituents upon corn, Prof. Atwater says.

> Superphosphate has proved profitable for corn usually. It has been most useful on the poorer and medium soils. With corn on rich soils it has had less, and sometimes no effect.
>
> Muriate of potash proved profitable with corn very frequently. Contrary to the common doctrine, potash did not prove more efficient with other fertilizers then when used alone, though, of course, the best results were obtained where it was used with other fertilizing materials. It is noticeable that in some cases of drought, or where the fertilizers were applied in the hill or drill, both muriate of potash and nitrate of soda were often injurious; with the mixture, too, this was especially the case.
>
> Nitrate of soda, where used either alone or with other materials on corn, was generally unprofitable, though in a few cases the results are very striking.

ADDENDUM.

The statistical tables on the preceding pages have been simplified to the utmost, in order that the point in which the farmer is most interested —the effect of fertilizers upon the yield of grain—may be most clearly illustrated. It seems, however, desirable to put on record the original data from which these tables were compiled, and this is done in Table XII.

COMMERCIAL FERTILIZERS—TABLE XII. EXPERIMENTS ON CORN.

Original Data.

Experimenter.	Size of plots.	Plot No.	Number stalks to full stand.	Number stalks missing.	Number stalks barren.	Yield per plot.			
						Ears.	Nubbins.	Total grain.	Stalks.
						Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Station.	One-tenth acre.	1	960	117	37	324	80	404	310
		2	960	163	38	320	69	389	280
		3	960	123	32	300	72	372	300
		4	960	80	25	372	67	439	330
		5	960	68	36	377	66	443	354
		6	960	63	63	371	82	453	340
		7	960	108	49	300	77	377	310
		8	960	132	77	321	72	393	330
		9	960	135	85	357	58	415	360
		10	960	103	60	334	52	386	340
		11	960	84	57	393	65	458	320
		12	960	57	54	360	62	422	380
		13	960	49	51	385	66	451	350
		14	960	62	60	333	71	404	344
		15	960	88	78	278	84	362	300
		16	960	53	72	291	85	376	260
		17	960	47	32	296	86	382	360
		18	960	57	57	327	76	403	320
		19	960	57	63	264	102	366	280
		20	960	22	79	374	82	456	344
		21	960	34	45	435	56	491	370
		22	960	66	43	333	68	401	290
Columbiana County. H. Y. BENTLEY.	One-tenth acre.	1	960	35	82	....	....	360	269
		2	960	24	80	....	....	282	271
		3	960	32	52	....	....	381	290
		4	960	26	48	....	....	395	290
		5	960	11	45	....	....	405	300
		6	960	13	64	....	....	429	312
		7	960	26	15	....	....	449	320
		8	960	30	69	....	....	427	340
		9	960	18	27	....	....	461	348
		10	960	25	43	....	....	425	311
		11	960	22	50	....	....	453	328
		12	960	7	48	....	....	513	372
		13	960	35	46	....	....	391	293
		14	960	28	44	....	....	408	294

COMMERCIAL FERTILIZERS—TABLE XII. EXPERIMENTS ON CORN—Continued.

Original Data.

Experi-menter.	Size of plot.	Plot No.	Number stalks to full stand.	Number stalks missing	Number stalks barren.	Yield per plot. Ears.	Nubbins	Total grain.	Stalks.
						Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Licking County. LEVI KNOWLTON.	One-twentieth acre.	1	486	....	....	137	20[1]	157	136
		2	486	....	....	180	25	205	150
		3	486	....	....	236	27	263	178
		4	486	....	....	202	33	235	208
		5	486	....	....	167	32	199	166
		6	486	....	....	238	21	259	196
		7	486	....	....	186	25	211	174
		8	486	....	....	183	26	209	210
		9	486	....	....	171	32	203	176
		10	486	....	....	179	31	210	196
		11	486	....	....	169	19	188	158
		12	486	....	....	223	24	247	168
		13	486	....	....	216	20	236	198
		14	486	....	....	182	22	204	160
		15	486	....	....	213	23	236	162
		16	486	....	....	236	24	260	178
Ashtabula County. GEO. H. BUNNELL.	One-tenth acre.	1	....	....	....	109	112	221	....
		2	....	....	....	245	114	359	....
		3	....	....	....	152	130	282	....
		4	....	....	....	119	104	223	....
		5	....	....	....	121	111	232	....
		6[2]	....	....	....	282	108	390	....
		7	....	....	....	139	111	250	....
		8[3]	....	....	....	190	104	294	....
		9	....	....	....	160	89	249	....
		10	....	....	....	115	104	219	....
		11	....	....	....	241	84	325	....
		12	....	....	....	247	93	340	....
		13	....	....	....	102	101	203	....

1 "Unsound corn."
2 "Corresponds to plot 8 in the other tables."
3 " " 6 " "

COMMERCIAL FERTILIZERS—TABLE XII—EXPERIMENT OF CORN—Concluded.

Original Data.

Experimental size.	Size of plots.	Plot No.	Number stalks to full stand.	Number stalks missing.	Number stalks barren.	Yield per plot.			
						Ears.	Nubbins	Total grain.	Stalks.
						Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Huron County, W. B. HALL.	One-twentieth acre.	1	728	85	361	....	....	39	65
		2	728	123	165	....	....	101	97
		3	728	140	281	....	....	58	84
		4	728	144	308	....	....	44	64
		5	728	119	305	....	....	56	66
		6	728	100	196	....	....	103	97
		7	728	162	230	....	....	81	96
		8	728	195	123	....	....	118	113
		9	728	140	202	....	....	103	118
		10	728	201	249	....	....	64	78
		11	728	79	219	....	....	105	99
		12	728	129	170	....	....	112	92
		13	728	137	335	....	....	52	59
		14	728	126	288	....	....	81	69
		15	728	208	193	....	....	80	72
Miami County, B. E. FURNAS.	One-twentieth acre.	1	804	329	101	35	64	99	54
		2	804	297	90	56	71	127	79
		3	804	273	109	53½	72	125½	78
		4	804	311	103	40	63	103	67
		5	804	298	53	59	74	133	83
		6	804	301	60	88	62½	150½	94
		7	804	316	89	46	69	115	72
		8	804	271	70	95	63	158	98
		9	804	295	46	90	64	154	98
		10	804	302	90	44	68	112	71½
		11	804	242	39	138	60	198	129
		12	804	320	75	76½	54	130½	96½
		13[4]	804	300	58	52	72	124	77¾
		14[5]	804	310	112	41	68½	109½	67¾
		15	804	311	129	24	57	81	60
Butler County, B. H. BROWN.	One-tenth acre.	1	....	....	....	....	....	128	132
		2	....	....	....	....	....	251	269
		3	....	....	....	....	....	2[illegible]2	270
		4	....	....	....	....	....	181	185
		5	....	....	....	....	....	187	200
		6	....	....	....	....	....	250	265
		7	....	....	....	....	....	194	210
		8	....	....	....	....	....	349	340
		9	....	....	....	....	....	265	255
		10	....	....	....	....	....	163	175
		11	....	....	....	....	....	336	337
		12	....	....	....	....	....	472	468
		13	....	....	....	....	....	206	202
		14	....	....	....	....	....	233	238

[4]Land plaster.
[5]Unfertilized.

COMMERCIAL FERTILIZERS ON OATS.

FIELD TEST AT THE STATION.

The plat upon which this experiment is located lies immediately south of the one devoted to similar experiments with corn; the plots and drains are continuous, and the fertilizers are applied in the same order, according to the plan given in table I.

The land was underdrained in April and May, 1888; a crop of millet was grown that season, and the oat crop of 1889 is the first crop of oats raised on this land for twelve years or more.

The results of the experiment are given in Table XIII, from which it will be seen that it cannot safely be asserted that any of the fertilizers applied were of any benefit to the crop. Certainly, none have paid their cost in increase of produce

It is true that plot 3, dressed with muriate of potash, shows a larger yield than the adjoining unfertilized plot; but plots 9, 10, 12 and 14 received an equal quantity of potash, yet their increase is insignificant.

COMMERCIAL FERTILIZERS—TABLE XIII.—EXPERIMENTS ON OATS AT THE STATION.

Plot No.	Fertilizers.	Yield per acre. Grain.	Yield per acre. Straw.
		Bushels.	*Pounds.*
1	Unfertilized	44.2	3,180
2	Superphosphate (dissolved bone-black)	46.9	3,520
3	Potash (muriate)	59.5	4,220
4	Unfertilized	48.2	3,800
5	Nitrate of soda	47.2	3,980
6	Nitrate and superphosphate	48.4	4,068
7	Unfertilized	45.0	3,640
8	Superphosphate and potash	45.0	3,660
9	Nitrate and potash	48.4	4,040
10	Unfertilized	47.5	3,960
11	Superphosphate, potash and nitrate	52.9	4,400
12	Superphosphate, potash and nitrate	47.8	4,300
13	Unfertilized	46.8	3,820
14	Superphosphate, potash and nitrate	45.0	3,880
15	Superphosphate, potash and ammonia	51.8	4,060
16	Unfertilized	36.5	3,200
17	Rock phosphate, potash and nitrate	47.3	3,800
18	Slag phosphate, potash and nitrate	45.7	3,500
19	Unfertilized	37.9	3,060
20	Barnyard manure	42.8	3,140
21	Linseed oil-meal	50.6	4,100
22	Unfertilized	46.1	3,800
	Average of unfertilized plots	44.0	3,557

Throughout the growing season, the plots that had received nitrogen showed a marked superiority; but these plots lodged badly before harvest, so that most of their advantage was lost.

This result was not unexpected. The problem of securing larger crops of oats is rendered doubly complex by the tendency of this plant to lodge when well fed.

COMMERCIAL FERTLIZERS ON WHEAT.

Chemical, or commercial fertilizers, were almost unknown in Ohio a dozen years ago, outside of a few counties in the extreme eastern and northeastern parts of the State. Statistics collected during recent years, however, indicate that the use of these fertilizers is steadily increasing, and that the farmers of the State are now spending not less than a million dollars annually in their purchase, three-fourths of which expenditure is made for fertilizers to be applied to the wheat crop.

In Europe these fertilizers have been used for a longer period, and in one case an exact comparative experiment has been made, which has now been in progress nearly half a century. Some of the results of this experiment are worthy the careful study of Ohio farmers.

COMMERCIAL FERTILIZERS—TABLE XIV.—WHEAT AT ROTHAMSTSD. AVERAGE YIELD FOR 36 YEARS.

Plot No.	Fertilizers per acre per annum.	Yield per acre.	Increase per acre.
		Bushels.	*Bushels.*
0	1,176 lbs. superphosphate[1]	16¼	3¼
1	800 lbs. sulphates of potash, soda and magnesia	13	0
2	Farmyard manure, 14 tons	33¾	20¾
3	Unfertilized	13	....
5	392 lbs. superphosphate and 400 lbs. sulphates of potash, soda and magnesia[2]	15⅛	2⅛
6	Superphosphate, etc., as in 5 and 200 lbs. amm. salts	24	11
7	" " 400 "	32¾	19¾
8	" " 600 "	36½	23½
9*a*	" " 550 lbs. nit. of soda	36	23
9*b*	550 lbs. nitrate of soda alone	23⅜	10⅜
10*a*	400 lbs. ammonia salts alone	20½	7½
11	392 lbs. superphosphate and 400 lbs. ammonia salts	25¾	12¾
13	392 lbs. superphosphate, 400 lbs. ammonia salts, and 200 lbs. sulphate of potash	31½	18½

[1] Made of 200 lbs. bone ash to 150 lbs. sulphuric acid.
[2] 200 lbs. sulphate potash, 100 lbs. sulphate soda and 100 lbs. sulphate magnesia.

In 1843 a wealthy young Englishman, John B. Lawes, now Sir John Lawes, began the study of the effect of various kinds and combinations of natural and artificial fertilizers on wheat and other crops. "Broadbalk Field" of his "Rothamsted Farm" was devoted to the continuous culture of wheat with fertilizers, the field being divided into a number of plots, each of which received the same application of manure or fertilizer year after year. Some of the results of this work are grouped in the above table, which gives the fertilizers applied annually per acre, and the average annual yield of wheat per acre, for the 36 years, 1852–87:

This table shows, that in this remarkable experiment, potash, when used alone, has produced no increase of crop. Phosphoric acid when used alone, albeit in very large quantity, has produced a very small increase. Nitrogen alone, both in the form of ammonia and of nitrate, has produced considerable increase.

Potash and phosphoric acid in combination have produced practically no increase until nitrogen was added, and then the increase was very much greater than that produced by nitrogen alone (compare 9*a* and 9*b*).

Comparing 11 with 13, we see that potash, though apparently useless when used alone, or with phosphoric acid only, yet has had a striking effect when added to a combination of phosphoric acid with nitrogen.

Comparing 13 with 7, it will be seen that the soda and magnesia have added very little to the value of the potash.

It is estimated that 400 pounds ammonia salts, such as are used in this test, will contain about the same quantity of nitrogen as 550 pounds nitrate of soda; but a comparison of 8 with 9*a*, and of 9*b* with 10*a*, shows that ammonia has been less efficient than nitrate in this experiment.

Omitting the soda and magnesia as useless, the cost, at present prices, of the superphosphate, potash, and ammonia salts applied to plot 6 would amount to about $17 per acre per annum; the application to plot 7 would cost about $25, and that to plot 8 about $33. Nitrogen may be purchased more cheaply, however, in the form of nitrate of soda, than in ammonia; and on this account, the fertilizers for plot 9*a* might be purchased for $23—or one dollar's worth of fertilizer for each bushel of increase.

The soil upon which this experiment is conducted is clay underlaid with chalk. In order to test the behavior of sandy land under fertilizers, the Royal Agricultural Society of England instituted in 1876 an experiment at Woburn, similar in its details to the one just described. A compilation of the results of the first ten years' work gives the following averages:

COMMERCIAL FERTILIZERS—TABLE XV.—WHEAT AT WOBURN. AVERAGE YIELD FOR 10 YEARS.

No.	Fertilizers per acre per annum.	Yield per acre.	Increase per acre.
		Bushels.	*Bushels.*
1	Farm-yard manure, 8 tons	26.7	9.6
2	Unfertilized	17.1	....
3	392 lbs. superphosphate and 400 lbs. sulphate of potash, soda and magnesia	17.7	0.6
4	275 lbs. nitrate of soda alone	24.1	7.0
5	275 lbs nitrate of soda with superphosphate, etc., as in 3	32.4	15.3
6	550 lbs. " " " "	37.1	20.0

Here again we have practically the same results on the sandy soil at Woburn, as those shown by the Rothamsted experiments on clay. Potash and phosphoric acid produce practically no effect until combined with nitrogen; but if we would get the full effect of a nitrogenous manure, we must add to it potash and phosphoric acid. Moreover, in both these experiments the fertilizers have been used with greatest economy when the quantity of nitrogen in the fertilizer was equal to, or greater than that of the phosphoric acid (nitrate of soda contains about 16 per cent. of nitrogen, and the superphosphate, used in these experiments, about the same per cent. of phosphoric acid).

These experiments further show that chemical fertilizers may be so used as to give at least as large an increase of crop as may be obtained from the liberal use of barn-yard manure; but in the Rothamsted experiment, each ton of such manure has yielded a bushel and a half of wheat, and in the Woburn experiment, each ton has yielded more than a bushel of wheat, whereas the most successful use of fertilizers has produced but a bushel of increase for the expenditure of a dollar in fertilizers, and when the fertilizers were not used in proper combination the cost of the increase has been much greater.

Ohio farmers, however, do not generally cultivate wheat continuously on the same soil, but alternate wheat with other crops; and those who use commercial fertilizers generally believe that such fertilizers applied to wheat are of special service to the grass crop following; clover being considered a "grass" in farm practice. On this point, Sir John Lawes has been experimenting for many years; but much of this part of his work has been defeated by what the English farmer knows as "clover sickness," something unknown in Ohio In summing up the results of his investigations he says:

When land is not what is called "clover sick," the crop of clover may frequently be increased by top dressings of manure containing potash and superphosphate of lime; but the high price of salts of potash, and the uncertainty of the action of manures upon the crop, render the application of artificial manure for clover a practice of doubtful economy.

At the Ohio Experiment Station a series of field experiments with fertilizers was inaugurated soon after the establishment of the Station, in 1882. These experiments have been conducted, from necessity, on a small area of unevenly drained land, the plots being from $\frac{1}{64}$ to $\frac{1}{32}$ acre in size. *The result of six years' work is that, as a rule, no more wheat has been harvested from the plots treated with commercial fertilizers than from those receiving no fertilizer, whereas the manures of the farm have produced a marked increase of crop when judiciously used.* We do not regard this experiment, however, as at all conclusive. It is evident that uneven drainage, surface washing over the small plots, and other sources of error which could only become apparent after some years' experience in the work is obscuring its results, and therefore it has been decided to abandon the work in this field and begin anew in another field, where a larger area may be devoted to it, and where thorough drainage is practicable.

The general plan of this experiment has been already described.

The section alloted to wheat lies with a gentle slope to the north—not more than sufficient for good drainage—and a barely perceptible dip to the east. On the east stands a grove of timber—chiefly beech and elm—while the other three sides are unprotected, except by the lay of the land. The subsoil is boulder clay, generally impervious to water. Before being drained, the soil became very wet and "spongy" in wet seasons. The slate is probably 10 to 15 feet from the surface, with no gravel intervening, except under a few of the western plots, where it is more than six feet from the surface.

The fertilizers were distributed according to the plan given in Table I, and the experiment was carried out under the immediate supervision of Mr. J. Fremont Hickman, Agriculturist of the Station.

COMMERCIAL FERTILIZERS—TABLE XVI.—EXPERIMENTS ON WHEAT AT THE STATION.

Yield per acre, with increase or decrease on fertilized plots.

Plot No.	Fertilizers.	Yield per acre.		Increase or Decrease. (—)
		Grain.	Straw.	
		Bushels.	*Pounds.*	*Bushels.*
1	Unfertilized	50.5	7,100	....
2	Superphosphate (dissolved bone-black)	50.2	7,220	2.9
3	Potash (muriate)	47.5	6,700	3.5
4	Unfertilized	40.8	6,140	....
5	Nitrate of soda (480 lbs.)	40.0	5,960	—3.0
6	Nitrate (480) and superphosphate	40.8	5,960	—4.5
7	Unfertilized	47.5	6,900	....
8	Superphosphate and potash	41.6	5,800	—5.4
9	Nitrate (480) and potash	45.6	7,240	—0.9
10	Unfertilized	46.0*	6,140	....
11	Superphosphate, potash and nitrate (480)	49.5	7,240	4.1
12	" " (320)	49 3	7,220	5.5
13	Unfertilized	44.2	5,200	....
14	Superphosphate, potash and nitrate (160)	47.0	5,740	4.9
15	" " ammonia	47.0	6,740	7.1
16	Unfertilized	37.8	5,900	....
17	Rock phosphate, potash and nitrate (480)	40.0	5,860	1.3
18	Slag " " (480)	39.3	5,900	—0.3
19	Unfertilized	40.5	6,000	....
20	Barn-yard manure	44.5	6,700	5.3
21	Linseed oil-meal	38.7	4,940	0.7
22	Unfertilized	36.7	4,860	....
23	Lime	37.0	5,200	....
24	Stable manure, bedded with shavings	33.1	5,140	....

* Estimated.

Table XVI shows that the results attained are almost wholly negative. A few of the fertilized plots have given larger yields than the adjoining unfertilized plots, but these increased yields have not occurred with sufficient regularity to justify the assumption that they are due to the fertilizers. Apparently, the soil of this field contained all the elements of fertility in sufficient abundance to satisfy the full capacity of the crop.

FARM TESTS.

But two complete farm tests were undertaken with wheat, one in Columbiana county, by Mr. H. Y. Bentley, and one in Erie county, by Mr C. A. Hawley. On account of delays in shipment of fertilizers from New York, the seeding in case of both these tests was delayed two to three weeks beyond the proper season, much to the detriment of the crop. In Mr. Hawley's experiment, the wheat grown on the test plots was practically destroyed by rust. The results obtained in Mr. Bentley's experiment are given in Table XVII, and indicate that nitrate of soda and superphosphate were of some benefit to the crop.

COMMERCIAL FERTILIZERS—TABLE XVII.—EXPERIMENTS ON WHEAT IN COLUMBIANA COUNTY, BY H. Y. BENTLEY.

Plot No.	Fertilizers.	Yield per acre.		Increase.
		Grain.	Straw.	
		Bushels.	*Pounds.*	*Bushels.*
1	Unfertilized	9.3	2,040	....
2	Superphosphate (dissolved bone-black)	13.3	2,540	3.7
3	Potash (muriate)	11 0	2,200	1.2
4	Unfertilized	10.1	2,260	....
5	Nitrate of soda (480 lbs.)	13.3	2,940	3.4
6	Nitrate (480) and superphosphate	15 0	3,060	5.3
7	Unfertilized	9 5	2,120	....
8	Superphosphate and potash	9.3	1,860	1.1
9	Nitrate (480) and potash	10.5	2,300	3.4
10	Unfertilized	6.0	1,540	....
11	Superphosphate, potash and nitrate (480)	10.6	2,200	5.9
12	Barnyard manure	4.1	1,200	0.8
13	Unfertilized	2.0	700	....
14	Common salt	1.5	590	....

In the tests just described, both that at the Station and that in Columbiana county, the nitrate of soda was sown in the fall, which was probably a mistake, as, when sown at that season, it is liable to be largely washed away by the rains and snow of winter and early spring. German experimenters, who have investigated this question carefully, advocate delaying the application of the chief part of the nitrate of soda used on a crop of wheat until April or even May. In the Rothamsted and Woburn experiments, nitrate of soda is not applied until spring.

The Rothamstead and Woburn experiments indicate so forcibly the necessity of a large proportion of nitrogen in a fertilizer for wheat, tha during the fall and winter of 1888–9 a few farmers in different parts of the State were induced to make the experiment of adding in the spring a small application of nitrate of soda to wheat that had already had bone-meal, or a similar phosphatic fertilizer, in the fall.

The plan of this experiment, as proposed to these farmers, was that when sowing the fertilizer in the fall, one or two strips should be left without any fertilizer, one should have an application of barnyard manure, and two should be dressed with bone-meal alone, one of which should have, in addition, an application of nitrate of soda and muriate of potash in the spring, at the rate of 160 pounds each per acre. The results ot this work are as follows:

Mr. D. J. Johnston, of Columbiana county, Ohio, made the experiment on a "rather cold and heavy clay soil, light timothy sod, plowed for corn and followed by oats." The plots were 3-16 acre each in size, and yielded as follows, in bushels, per acre:

No. 1.	Unfertilized	8 6
No. 2.	S. C. rock, 400 lbs. per acre	15.8
No. 3.	S. C. rock, 400 lbs., followed by nitrate and potash	22.4
No. 4.	Unfertilized	14.3
No. 5.	Barnyard manure	12.3

Mr. Johnston explains that plot No. 1 was behind from the start, as it did not come up so well as the others, and that the barnyard manure was put on when the ground was frozen, and was not very well rotted.

Mr. E. L. McCague, of Huron county, reports the following yields:

Plot 1.	Unfertilized	3.1
" 2.	Bone-meal, 400 lbs. per acre	5.4
" 3.	Bone-meal, 400 lbs. per acre, followed by nitrate and potash	17.4
" 4.	Unfertilized	4.4
" 5.	Barnyard manure	28.4

Mr. McCague writes that the average yield of the field in which this experiment was located was 20 bushels per acre; but the experiment plot was sown September 27, two weeks later than the remainder of the field, and suffered from drouth.

Mr. Orlando Hickey, of Licking county, reports as follows:

Plot 1.	Bone-meal	33.3
" 2.	" followed by nitrate and potash	50.6

Mr. Orlando Trotter, of Washington county, undertook the same experiment, but misunderstood the plan, and instead of putting the nitrate and potash on a plot that had been dressed with bone in the fall, he put it on one that had had no fertilizer. He reports the following yields:

Plot No. 1.	Bone-meal, 225 lbs. per acre	16½
" " 2.	Nitrate and potash	20⅚

Mr. W. C. Pinkham, of Clermont county, undertook the experiment, but as he could see no difference in the growth of the different plots, did not harvest them separately. It is not safe, however, to rely upon the eye alone in such work as this.

It will be seen that in the three tests in which the plan was fully carried out and the results carefully ascertained, there has been a very decided increase of crop from the spring application of nitrate and potash.

It would have been better if the nitrate had been used alone on one plot, and in combination with potash on another, in order to determine, beyond possibility of mistake, which of the two substances is needed by the plant. To this end the following very simple experiment is proposed, in the earnest hope that a large number, out of the many thousand farmers who will receive this bulletin, may be induced to undertake it and carry it carefully to completion.

The object of the experiment is simply to determine whether nitrate of soda may be profitably used as a fertilizer on wheat that has already received a fall dressing of some fertilizer rich in phosphoric acid and poor in nitrogen, such as bone-meal. In other words, it is designed to ask our soils whether the ratio of nitrogen to phosphoric acid may be profitably increased, when manuring them for wheat, above the ratio found in the average of the commercial fertilizers sold in the State.

As the foundation for the experiment, therefore, take a field that has had a dressing of bone or other phosphate in the fall; on that side where the soil is most uniform, stake off four strips, as per the diagram following.

Outside of the strips, and across the ends, leave a space not less than two rods wide, and wider if near timber, in order that the results may not be vitiated by the influence of fence or trees. Two of the strips are to be left with phosphate only; one is to receive nitrate of soda, at the rate of 160 pounds per acre, and one nitrate at the same rate and muriate of potash at the rate of 40 to 80 pounds. (As most of the "phosphates" used with wheat in Ohio contain some potash, and as potash seems to be less often required than nitrogen or phosphoric acid, the quantity named is believed to be sufficient. The larger quantity is proposed for tests in which bone-meal has been used, the smaller one for those in which a fertilizer containing potash has been used.)

1. Phosphate only, in Autumn
2. Phosphate in Autumn, Nitrate in Spring.
3. Phosphate in Autumn, Nitrate and Potash in Spring.
4. Phosphate only, in Autumn.

Let the strips be of sufficient size to contain at least one-tenth acre each—larger will be better—and apply the nitrate and potash broadcast at any time from the middle of April to the middle of May.

In harvesting first draw lines from stake to stake around the boundaries of the entire plot and along the divisions, then with a sickle cut aisles about 16 inches wide under each line. Then cut off the outside belt and set its sheaves to one side, after which the remaining strips can be cut without difficulty.

Thresh from the shock if possible; otherwise, stack the plots with layers of hay between, weighing the sheaves of each plot, if possible, before stacking. In threshing, let the machine run empty between plots (it is not necessary to stop it) and sack and securely label the grain from each plot as it runs from the machine. It is well to drop a duplicate label inside the sack, to guard against accident.

Nitrate of soda and muriate of potash are not generally kept in stock by dealers in fertilizers, but most dealers will be glad to order them for their customers. The probable cost, in small lots, will be about 3 cents per pound, freight, commission, etc., included.

EXPERIMENTS ON PLANTS GROWN IN BOXES.

Whoever has carefully looked over the tables given on the preceding pages, must be struck with the great diversity in natural productiveness of soils selected because of their apparent uniformity, as shown by the differences in yield of the unfertilized plots. These differences, however, are not exceptional, but are quite within the limits of variation which practical field experimenters have learned to expect in such work.

By systematic and continuous cultivation of a series of plots, under uniform treatment, such inequalities as have arisen from temporary causes will gradually disappear, and in the course of years such results may be arrived at as those shown in the Rothamsted experiments, where it is evident that all minor inequalities in natural fertility have been obliterated in the grand aggregate results of a half-century of persistent work.

But we cannot afford to wait half a century for results Something must be definitely indicated from year to year, if field experimentation is to hold a permanent place as a practicable method of research.

By repeating the same experiment on various soils, after some such method as that explained on previous pages of this bulletin, some of the errors indicated may be in a measure corrected. But this method also leaves much to be desired. It does not remove the source of error, but is only useful because the inequalities of one soil are likely to be offset by different inequalities in another soil, and thus one error is made to counteract another.

The only method by which a soil of absolute uniformity can be secured is to deal with a quantity so small that it may be thoroughly mixed, after which experiments upon it may be conducted in pots or boxes, or in plots of very small size in the field, made by removing the surface soil to a uniform depth, mixing it thoroughly and returning it to the original situation.

The objections to this method of experiment are, that it involves the placing of the soil under abnormal conditions as to heat and drainage, if boxes or pots are used, and the dealing with such a limited number of plants in any case that the idiosyncrasies of individual plants, or the errors liable to arise from calculating acre yields from yields of single plants, or small numbers of plants, are liable to be very misleading. As one of several co-ordinate methods of investigation, however, in which the results of one method are used to verify those of another, the culture of plants in pots or boxes must hold an important place.

It is with this end in view that such experiments as those about to be described are being made.

In the spring of 1888 two series of boxes, each box being 18 inches square by 12 inches deep, were filled, the one series with clean sand from the beach of Lake Erie, the other with mixed soil from the field in which the Station's fertilizer experiments are installed, and planted with carefully selected grains of corn.

The boxes were so arranged as to have uniform drainage, and around them corn of the same variety was planted in the open ground, to insure fertilization of the ears.

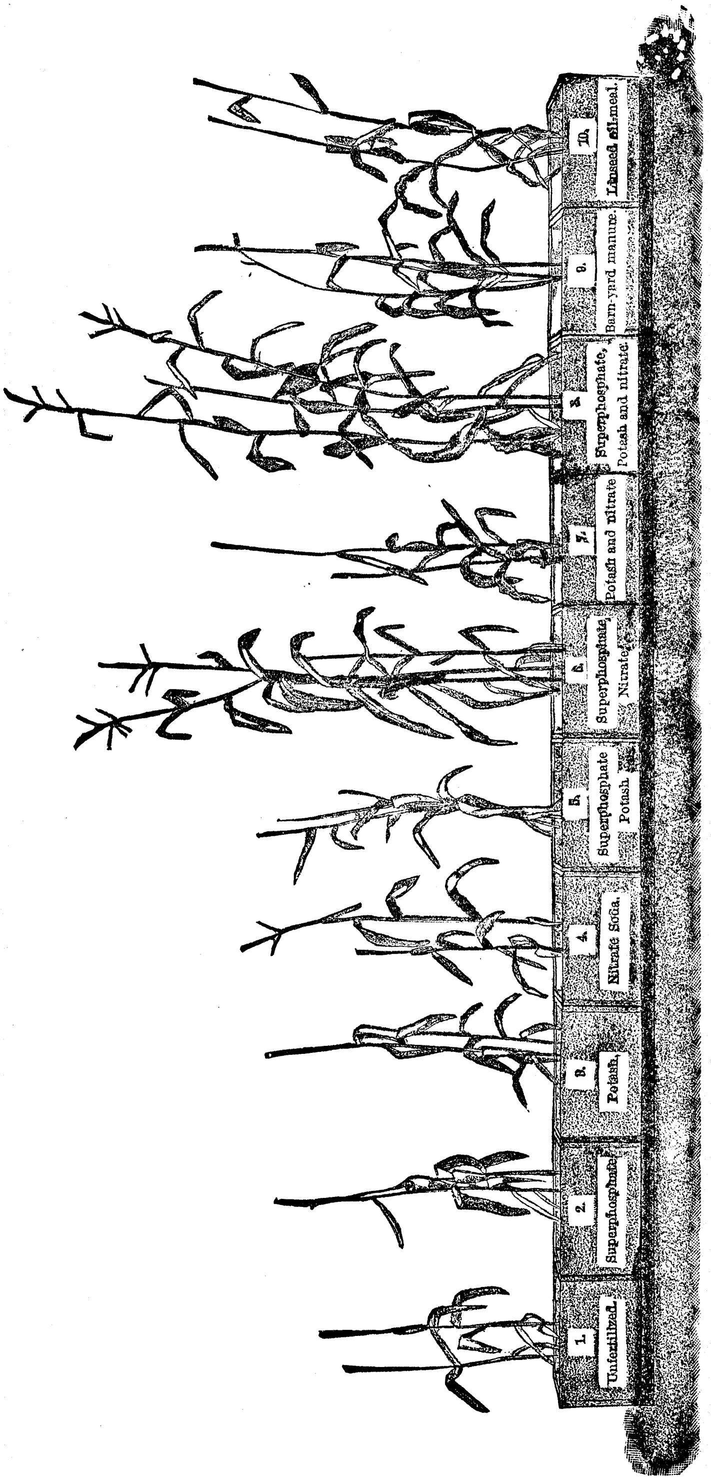
At planting time, and at intervals during the growth of the corn, dissolved bone-black, muriate of potash and nitrate of soda were applied to the soil of the different boxes, singly and in various combinations, and also barn-yard manure and linseed oil-meal, according to the plan shown in plate I, which is drawn from a photograph of the boxes containing lake sand and taken when the corn had reached maturity.

It will be seen that in only two cases did the plants reach anything approaching complete development; those being in the boxes which had received nitrate and superphosphate in the one case, and nitrate, superphosphate and potash in the other. The total dry weight of the plants grown in box 6 was 6.25 ounces, containing 1.62 ounces grain; that of the plants grown in box 8 was 9.50 ounces, containing 2.25 ounces of grain, these being the only plants that produced any grain, thus showing that whereas potash alone, or in combination with either phosphoric acid or nitrogen, was of no service to the plant, yet when combined with both phosphoric acid and nitrogen it produced a marked increase—a result in striking harmony with the half century's experiments with wheat at Rothamsted.

In the boxes containing the soil of the experiment field, the plants all reached about the same altitude, and each box produced a little grain; but the quantity of grain produced was in proportion to the quantity of nitrogen added.

In the fall of 1888, wheat was sown in these boxes, the soil being left undisturbed, and the same fertilizers were applied to the wheat as had been to the corn. The wheat was watched carefully throughout the season, and when it was necessary to water it artificially the water was measured, so as to give the same quantity to each box. The fertilizers were applied at different periods, and the same quantity of each ingredient was given to each box. No attempt was made to calculate quantities per acre, the object being simply to give an abundance of each of the three substances, nitrogen, phosphoric acid and potash. The results are shown in plates II and III. The horizontal lines shown represent spaces of six inches, and show that the most vigorous plants made a growth of nearly three feet from the surface of the soil. When growing in the field, under unrestricted conditions, the variety of wheat used in this work (Penquite's Velvet), reaches a height of three to four feet.

In all cases the same number of grains of wheat were sown; the increase of stand in the fertilized boxes is due to the increased stooling of the wheat under the conditions of prosperity it found there. In both series of boxes the futility of using for wheat a fertilizer containing no nitrogen, as well as the inadequacy of nitrogen, when not aided by phosphoric acid, is strikingly demonstrated.



COMMERCIAL FERTILIZERS—PLATE I.—CORN GROWN IN LAKE ERIE SAND.

It will be noticed that in the series of boxes containing soil from the experiment field the wheat in the three boxes fertilized with the combinations of nitrate with potash and superphosphate, is much shorter than in the other boxes. The heads, however, were evenly and well filled, and the growth very dense. There could be no question, with one who saw the wheat growing, that boxes 6 and 8 contained much more grain than any others in the series, except No 10.

Unfortunately, the English sparrows prevented the absolute demonstration of this point by harvesting the grain for themselves one Sunday afternoon.

In a series of these boxes, containing lake sand, German millet was grown in 1889 The final weights of the crop are given in table XVIII.

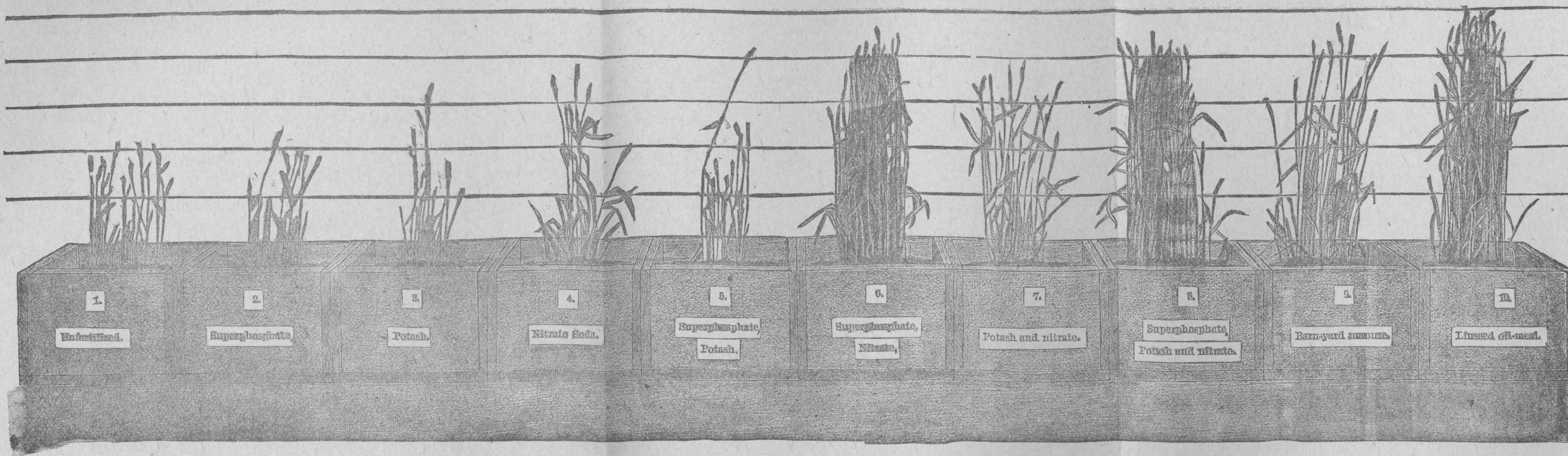
COMMERCIAL FERTILIZERS—TABLE XVIII. Experiment on German Millet in Boxes

Box No.	Fertilizer.	Weight of crop.	
		Grain.	Straw.
		Grammes.	*Grammes.*
1	Unfertilized	7	19.1
2	Superphosphate (dissolved bone-black)	.7	19.1
3	Potash (muriate)	.5	22.2
4	Nitrate soda	1.5	41.0
5	Superphosphate and potash	7	22.0
6	Superphosphate and nitrate	4.5	83.4
7	Potash and nitrate	1.5	41.0
8	Superphosphate, potash and nitrate	10.0	141.7
9	Barnyard manure	16.9	388.5
10	Linseed oil-meal	4.5	157.1

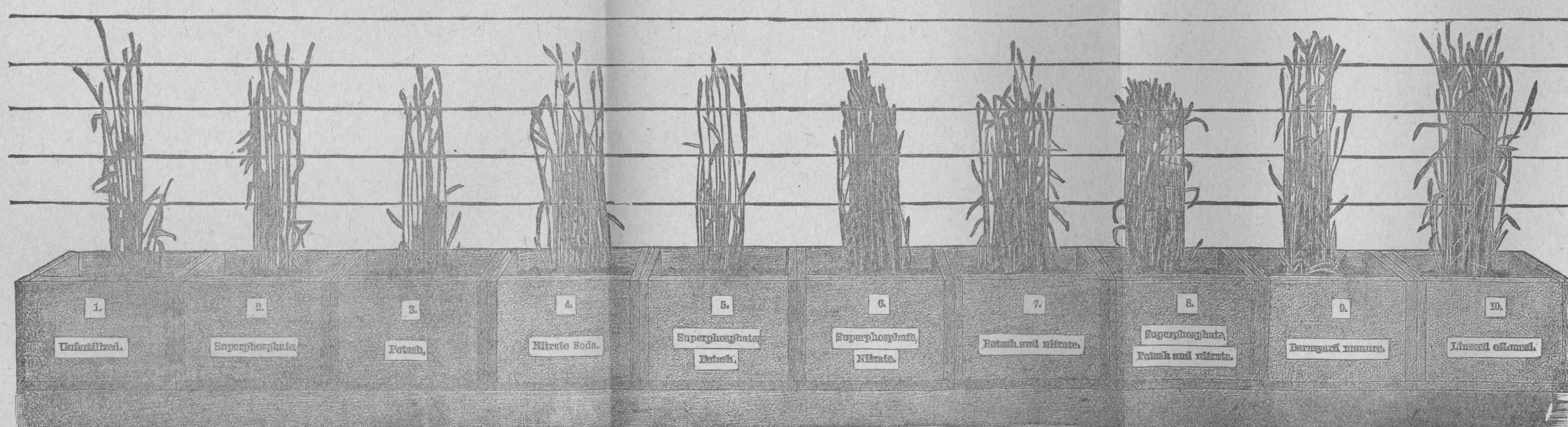
It will be observed that these results are in harmony with those of the other tests, except that barnyard manure shows a greater superiority. This is partly due to the fact that the boxes had already borne two crops before the millet, and the earlier applications of manure had become more thoroughly decomposed and incorporated with the sand.

We have two objects in view in illustrating these box experiments: The first is to add their testimony to that of the field experiments previously described, and the second is to suggest to farmers a very simple method of ascertaining the needs of their soils; a method within the reach of every farmer or farmer's boy; one more reliable than the most elaborate chemical analysis; more reliable, even, than an actual field test, under ordinary circumstances.

To make this test, simple pine boxes will be found most convenient.



COMMERCIAL FERTILIZERS—PLATE II.—WHEAT GROWN IN LAKE ERIE SAND.



COMMERCIAL FERTILIZERS—PLATE III.—WHEAT GROWN IN CLAY LOAM.

We have found the size mentioned, namely, 18 inches square by 12 inches deep, to be well suited for the small grains; for corn, however, we recommend field experiments, as it is not practicable to use boxes large enough to give proper root space to more than one or two plants, and there is such a great difference in the individuality of different plants of corn that experiments on single plants are liable to be misleading.

Believing that valuable suggestions respecting the needs of various soils may be obtained through this method of investigation, the Station makes the following proposition:

To any farmer who will undertake to carry out carefully on oats or wheat such a series of box tests as that illustrated in plates I to III, and to send the crop produced to the Station for final determinations, the Station will furnish free the fertilizers necessary for the experiment, with instructions for carrying out all its details.

GENERAL CONCLUSIONS.

These experiments seem to justify the conclusion that in fertilizing for wheat a much greater crop may be produced by using phosphoric acid and nitrogen in approximately equal quantities, the phosphoric acid being applied in the fall, the nitrogen (if used as nitrate) chiefly in the spring, than by the ordinary practice of using phosphates only.

They indicate that nitrogen may often, but not always, be omitted from a fertilizer for corn without detriment to the crop.

The most important conclusion to be drawn from these tests is, however, that in very many, if not the majority of cases, neither wheat nor corn will return sufficient increase of crop to cover the cost of any artificial fertilizer, at present prices of grain and fertilizers, respectively.

The experiments do not, however, furnish conclusive proof that commercial fertilizers cannot be used with profit in Ohio. Most persons who use these fertilizers on wheat do so in the belief that the grass or clover following the wheat is much improved by the fertilizer, and English experiments indicate that there is some justification for this belief. Whether this improvement is sufficient to compensate the average loss which must result in the wheat crop is a question which should be subjected to the test of systematic experiment.

Such experiments are now in progress at this Station, but the co-operation of farmers throughout the State is needed in order that results of general application may be reached at an early date.

ACKNOWLEDGMENTS.

All that portion of the field experiments above described which was performed at the Station, whether with corn, oats or wheat, was performed

under the personal supervision of Mr. J. Fremont Hickman, agriculturist of the Station, and John A. Alwood, farm foreman. Mr. Hickman has also rendered valuable assistance in the co-operative experiments and in tabulating the Station's work for publication

The box experiments described were carried out by Mr. W. H. Baker, meteorologist of the Station, and a student in the agricultural department of the University. To all these gentlemen credit is due for hearty co-operation and careful work.

THE SOURCES AND COST OF COMMERCIAL FERTILIZERS.

Phosphoric Acid.—There are four principal sources of the phosphoric acid of fertilizers: These are the bones of animals; a phosphatic rock, found in South Carolina, Florida and other places; a slag resulting from the manufacture of steel from iron ores containing phosphorus by the Thomas-Gilchrist process, and hence called "Thomas slag," and certain guanos.

Bones are used in two forms· namely, as raw bone-meal, and as superphosphate, which is made by treating raw bone or rock with sulphuric acid, which renders most of the phosphoric acid of bones, and a considerable portion of that of rock, easily soluble in water or weak acids. One of the most reliable forms of bone superphosphate is known as "dissolved bone black." In the refining of sugar, large quantities of bone charcoal are used. After a time, this charcoal becomes unfit for further use in refining, and is then sold as a fertilizer, for which purpose it may be used in the condition in which it comes from the refinery, as simple bone-black, or it may be first treated with sulphuric acid, and thus converted into "dissolved bone-black." Raw bones contain a small portion of nitrogen, but this is expelled in converting them into bone-black, hence the only fertilizing properties of bone-black are the phosphoric acid and lime which it contains. In treating bone-black with sulphuric acid, a portion of this lime is converted into sulphate of lime, or gypsum, and this, under certain conditions, may add to the value of the fertilizer, especially where potash is needed, as one of the functions of gypsum seems to be the liberation of potash from its combinations in the soil.

Experience has shown that dissolved bone black is one of the most reliable vehicles for conveying phosphoric acid to the soil. It is now offered at wholesale in New York at $22.00 per ton; adding 25 cents per hundred for freight and handling, it will cost in Ohio $27.00 per ton, or 8½ cents for each pound of phosphoric acid contained. Phosphoric acid may be bought for less money in the phosphatic rock of South Carolina, in Thomas slag, or in the phosphatic guanos, and experiments made by he Connecticut Experiment Station indicate that the phosphoric acid of guano and Thomas slag, at least, is almost as effective as that of dissolved bone-black, provided two or more seasons be given these fertilizers in wh ch to do their work, as their phosphoric acid is not so readily soluble as that of dissolved bone-black. The same may be said of the use of raw bone meal; if ground fine enough and given time enough it will yield to plants almost the entire amount of its phosphoric acid.

Potash.—The chief sources of the potash of commercial fertilizers are various salts of potash—muriate of potash, containing about 50 per cent. actual potash; high-grade sulphate of potash, containing about the same proportion of potash; double sulphate of potash and magnesia, containing 25 to 27 per cent. actual potash, and Kainit, containing about 12 per cent. actual potash. Muriate of potash is now offered at wholesale in New York at two cents per pound, thus making the cost of actual potash, in this form, about 4½ cents per pound in Ohio, including freight and commission. Although the lower grades of potash salts are sold at a much lower price than the muriate, the actual potash is contained in so much smaller proportion that it is often more expensive in the low priced than in the high priced salts, especially when the additional freight on the bulky, low priced salts is added.

The ashes of cotton hulls contain about 25 per cent. of potash and 1¼ per cent of phosphoric acid, on an average. Corn-cob ashes should contain as much potash, if reasonably free from impurities. Canada hardwood ashes are being offered for sale in Ohio as a potash fertilizer, at about $15 per ton. A large number of analyses of such ashes, made by the Connecticut Experiment Station, show that they contain about 6 per cent. of potash and 1½ per cent. of phosphoric acid. Estimating the phosphoric acid at its cost in dissolved bone-black, the potash would cost about 10 cents per pound. The lime in ashes is often of some value, especially on heavy clays; but a ton of ashes would not ordinarily contain more than 20 bushels of lime, which may be bought fresh from the kiln in most sections of the state at 18 to 25 cents per bushel, or about half what it would cost in the ashes, reckoning the potash at its cost in muriate.

Reducing Bones—Farmers frequently ask how they may reduce bones for their own use. The first step is to break them into small pieces, by grinding or pounding, they may then be mixed in alternate layers with stable manure, and allowed to ferment for ten or twelve months, after which they will be found soft and friable. They may also be reduced by packing them in barrels in alternate layers with wood ashes and occasionally moistening with barnyard liquor, or by boiling in lye made from wood ashes. The solution of bones with sulphuric acid is a difficult operation, and cannot be done with economy on an ordinary farm. Unless the bones are first ground to a very fine meal, the acid will form a coating on the outside of the pieces which will prevent its further action, and render the solution extremely tedious Even when the bones are thoroughly ground, the solution can be accomplished with greater economy by those who are prepared to do the work on a large scale, and who have acquired skill in the special manipulations required, than by the ordinary farmer.

Leached ashes contain about 1 per cent. of potash and 1 to 1½ per cent. of phosphoric acid, and these may sometimes be bought at a price that will justify their use.

Nitrogen.—The chief sources of the nitrogen of fertilizers are nitrate of soda, sulphate of ammonia, and dried blood and other slaughter-house refuse.

Nitrate of soda is a salt dug from the earth, chiefly in Peru and Chili. It is often called Chili saltpetre. As marketed, it should contain about 16 per cent. of nitrogen. It is now offered in the New York market at 2⅛ cents per pound, equivalent to 2⅜ or 2½ in Ohio, thus making its actual nitrogen cost about 15 cents per pound.

Sulphate of ammonia is a refuse product from the manufacture of illuminating gas. It contains about 20 per cent. of nitrogen, and is now quoted in New York at 3¼ cents per pound, making its nitrogen cost in Ohio about 17 cents per pound. Dried blood is a refuse of the slaughter-houses, and contains 9 to 13 per cent. of nitrogen. By "cornering" the market, the cost of nitrogen in this form has been raised to about 19 cents per pound.

The experiments of Sir J. B. Lawes have shown that as a fertilizer for wheat, nitrate of soda is more effective than sulphate of ammonia, pound for pound.

CHAS. E. THORNE, *Director.*

ADDENDUM.

ANALYSES OF FERTILIZERS.

The Station receives many requests for reports of analyses of fertilizers. In Ohio, this work is done, not by the Experiment Station, but by the State Board of Agriculture, under supervision of L. N. Bonham Secretary, by whom the reports of analyses are published and distributed.

As the facts exhibited by these analyses, in regard to the general composition of the commercial fertilizers sold in the State, have a direct bearing upon the question discussed in this bulletin, and as the edition published by the Board of Agriculture is not more than sufficient to supply the ordinary demand for it, it has been deemed proper to republish here the principal features of the tables of statistics, found in the latest report of analyses made by the Board of Agriculture.

The tables are published as corrected for this bulletin by Secretary Bonham, and are followed by an explanation of the method by which the valuations given are obtained, by Prof. N. W. Lord, State Analyst Fertilizers.

TABULATED ANALYSES AND VALUATIONS OF FERTILIZERS, UP TO DECEMBER 31, 1889.

[ISSUED BY THE OHIO STATE BOARD OF AGRICULTURE, JANUARY 15, 1890.]

The analyses are by Prof. N. W. Lord, Ohio State University, Columbus, Chemist of the Board of Agriculture. The samples were selected by the Secretary of the Board, in accordance with the act of March 16, 1881. All samples given are verified by oath on file in this office. The valuations are by the Secretary, and based on the average commercial value of the ingredients in Ohio, as sold at retail this year, viz., ammonia, 19 cents per pound; soluble and reverted phosphoric acid, 8½ cents; insoluble phosphoric acid in rock, 2 cents; insoluble phosphoric acid in animal matter, 5 cents; and potash, 6½ cents per pound.

[TABLE I.—Superphosphates and acidulated goods. See, also, Table II and notes.

Record number.	Name of fertilizer and address of manufacturer.	Per cent. of ammonia	Total per cent. of phosphoric acid.	Per cent. of insoluble phosphoric acid.	Per cent. of potash.	Estimated value per ton.	Record number.
1	Jarvis Drill Phosphate—Michigan Carbon Works, Detroit, Mich	1.36	11.75	1.27	....	$23 50	1
4	Homestead A Bone Black Fertilizer—Michigan Carbon Works, Detroit, Mich	3.40	10.35	0 83	2.11	32 67	4
7	Bone and Meat Phosphate—Vaughn, Bonsall & Co., Salem, O	6.84	14.82	6.32	2.03	49 40	7
8	Dissolved Bone—Vaughn, Bonsall & Co., Salem, O	3.10	14.76	4.98	....	30 40	8
9	Banner Bone Phosphate—Vaughn, Bonsall & Co., Salem, O	1 52	18.08	5.87	2.12	33 35	9
10	Peerless Bone Phosphate—Canton Fertilizer Co., Canton, O	3.40	5.11	1.40	3.61	24 48	10
12	Bradley's Dissolved Bone with Potash—Bradley Fertilizer Co., Boston, Mass	1.70	14.31	3.45	1.90	28 77	12
13	Sea Fowl Guano—Bradley Fertilizer Co., Boston, Mass	2.63	13.03	2 55	1.79	31 16	13
15	Grain and Grass Fertilizer—Great Eastern Fertilizer Co., Rutland, Vt.	2.89	11.62	0.96	2.29	32 46	15
16	Wheat Special—Great Eastern Fertilizer Co., Rutland, Vt	1.70	10.86	0.89	2.81	27 42	16
17	Oats and Buckwheat Phosphate—Great Eastern Fertilizer Co., Rutland, Vt	1.82	11.24	1.02	2.71	28 22	17
18	Vegetable, Vine and Tobacco Fertilizer—Great Eastern Fertilizer Co., Rutland, Vt	2.55	12.01	1.02	3.64	35 21	18
19	Diamond Soluble Bone—Walton, Whann & Co., Wilmington, Del	0.47	15.65	1.79	....	26 07	19
20	Diamond Soluble Bone and Potash—Walton, Whann & Co., Wilmington, Del	....	15.46	2.81	2.39	25 73	20
21	Button Bone Fertilizer—New Jersey Chemical Co., Philadelphia, Pa	1.95	11.63	1.34	2.64	28 87	21
22	Western Reserve Fertilizer—Western Reserve Fertilizer Co., Mineral Ridge, O	... .	0.17	....	....	0 .9	22
23	Queen City Phosphate—Crocker Fertilizer Co., Buffalo, N. Y	2.21	10.66	0.76	1.65	27 67	23
24	Superphosphate No. 2—Crocker Fertilizer Co., Buffalo, N. Y	....	14.04	0.63	1.41	24 88	24
25	Success Phosphate—Lister's Agricultural Chemical Works, Newark, N. J	1.87	11.75	1.40	1.49	27 21	25
26	U. S. Phosphate—Lister's Agricultural Chemical Works, Newark, N. J	1.78	9.20	1.79	2.73	23 63	26
27	American Dissolved Bone—Lister's Agricultural Chemical Works, Newark, N. J	2.12	12.01	1.34	1.22	28 33	27
28	Gilead Phosphate—Cincinnati Desiccating Co., Cincinnati, O	2.97	10.09	2.49	2 43	29 86	28
29	Tobacco Fertilizer—Cincinnati Desiccating Co., Cincinnati, O	7.39	11.69	2.42	3.49	50 80	29
30	Pure Acid Bone—Cincinnati Desiccating Co., Cincinnati, O	3.82	21.80	7.47	.....	44 65	30
38	Grond Bone with Potash—Bradley Fertilizer Co., Boston, Mass	2.21	12.65	2.81	2.94	31 76	33

TABULATED ANALYSES AND VALUATIONS OF FERTILIZERS, UP TO DECEMBER 31, 1889—Continued.

Record number.	Name of fertilizer, and address of manufacturer	Per cent. of ammonia.	Total per cent. of phosphoric acid.	Per cent. of insoluble phosphoric acid.	Per cent. of potash.	Estimated value per ton.	Record number.
34	Dissolved Bone with Potash—Bradley Fertilizer Co., Boston, Mass	1.19	10.09	1.27	2.52	$23 30	34
35	Sea Fowl Guano—Bradley Fertilizer Co., Boston, Mass	2.38	12.65	2.55	1.61	29 32	35
36	Potato Fertilizer—Bradley Fertilizer Co., Boston, Mass	2.29	12.68	1.50	3.18	31 42	36
38	Ohio Valley Phosphate—Cincinnati Desiccating Co., Cincinnati, O	1.87	9.45	2.74	2.01	22 23	38
39	Packing House Fertilizer—Cleveland Provision Co., Cleveland, Ohio	8.33	12.78	8.11	....	47 70	39
40	Challenge Corn Grower—N. W. Fertilizer Co., Chicago, Ill	2.21	14.69	7.15	0.21	28 64	40
41	Lindale Phosphate—Herrick, Harris & Co., Cleveland, O	1.95	17.90	6.20	....	33 50	41
42	Pride of Ohio Phosphate—Herrick, Harris & Co., Cleveland, O	2.04	13.24	2.88	....	26 51	42
44	Pure Bone and Potash Phosphate—Herrick, Harris & Co., Cleveland, O	2.81	17.70	6.78	3.64	40 75	44
46	Am. Bone Superphosphate—Crocker Fertilizer & Chemical Co., Buffalo, N, Y	3.74	11.24	1.27	1.58	33 72	46
49	Big Bonanza Fertilizer—Walker, Stratman & Co , Pittsburg, Pa	1.99	10.56	3.94	1.06	24 12	49
50	Ohio Seed Maker—Cleveland Dryer Co , Cleveland O.	1.40	15.08	5.43	....	23 89	50
53	Empire Superphosphate—Western Union Chemical Co., Cleveland, O	1.11	13.94	2.68	....	24 43	53
54	International Phosphate—Western Union Chemical Co., Cleveland, O	....	15.54	2.17	....	23 60	54
56	Forest City Am. Bone Superphosphate—Cleveland Dryer Co., Cleveland, O	....	14.57	4.28	0.21	19 48	56
57	Four Fold Fertilizer—Walker, Stratman & Co., Pittsburg, Pa	2.04	10.90	3.70	0.94	22 69	57
60	Ohio Farmer Bone Superphosphate—Western Union Chemical Co., Cleveland, Ohio	1.87	14.25	2.81	0.20	27 94	60
61	Guano—The Currie Fertilizer Co., Louisville, Ky	1.87	10.36	0.92	2.92	27 33	61
62	Pure Ammoniated Dissolved Bone—Loudenback & Co., Westville, Ohio	2.04	8.40	0.89	2.25	24 33	62
63	Dissolved Bone Phosphate and Potash—John S. Reese & Co., Baltimore, Md	....	15.97	5.11	1.43	22 36	63
64	Soluble Pacific Guano—Jno. S. Reese & Co., Baltimore, Md	2.55	12.14	3.70	1.36	27 29	64
65	Queen City Raw Bone Superphosphate—The Currie Fertilizer Co., Louisville, Ky	2.21	12.64	2.14	1.33	28 84	65
66	Queen City Corn Grower—The Currie Fertilizer Co., Louisville, Ky	1.95	12.44	3.62	1.22	25 44	66
67	Currie's Guano—The Currie Fertilizer Co., Louisville, Ky	2.39	9.96	1.98	3.03	27 35	67
68	Currie's Potato Grower—The Currie Fertilizer Co., Louisville, Ky	3.27	10.88	3.10	2.47	30 11	68
69	Currie's Tobacco Grower—The Currie Fertilizer Co., Louisville, Ky	2.93	11.10	2.95	2.72	29 71	69
71	Insecticide Floral Fertilizer—The Curry Fertilizer Co., Louisville, Ky	3.04	8.76	1.69	4.05	29 49	71
72	New Standard—E. O. Peters & Co., Cincinnati, O	2.41	8.42	0.76	3.44	26 95	72
73	Pure Acid Bone, Cincinnati Desiccating Co., Cincinnati, O	4.84	21.21	7.41	....	49 26	73
74	Ohio Valley Phosphate—Cincinnati Desiccating Co., Cincinnati, O	1.87	10.09	4.28	2.14	21 48	74
76	Tobacco Fertilizer—Cincinnati Desiccating Co., Cincinnati, O	4.38	13.67	3.32	5.85	45 15	76
78	Champion Fertilizer—Newburg Fertilizer Co., Newburg, O	3.40	12.84	2.82	....	31 08	78
80	Western Reserve Fertilizer—Newburg Fertilizer Co., Newburg, O	4.29	12.38	3.28	....	33 08	80
81	Forest City Am. Bone Superphosphate—Cleveland Dryer Co., Cleveland, O	5.25	13.36	2.30	0.27	40 02	81
82	Buckeye Am. Bone Superphosphate—Cleveland Dryer Co., Cleveland, O	3.82	14.60	2.52	0.33	36 50	82
83	Ohio Seed Maker—Cleveland Dryer Co., Cleveland, O	1.06	14.48	3.18	....	24 51	83
84	XXX Acid Phosphate—Cleveland Dryer Co., Cleveland, O	....	15.84	2.20	....	24 07	84
85	Potato Fertilizer—Cleveland Dryer Co., Cleveland, O	3.31	12.66	3.08	4.60	36 08	85

86	Sandy Soil Fertilizer—Cleveland Dryer Co., Cleveland, O	3.48	12.92	3.52	4.05	35 87	86
87	White Barley Tobacco Fertilizer—Cleveland Dryer Co., Cleveland, O	4.29	15.10	3.04	3.29	42 30	87
88	Bone and Potash Mixture—Cleveland Dryer Co., Cleveland, O	3.31	16.94	5.82	....	33 81	88
89	Conn. Valley Tobacco Fertilizer—Cleveland Dryer Co., Cleveland, O	3.82	15.33	3.14	3.21	40 67	89
92	Plain Dissolved Bones—Cleveland Dryer Co., Cleveland, O	0.43	15.48	1.94	....	25 43	92
93	Am. Dissolved Bone—Cleveland Dryer Co., Cleveland, O	2.04	13.82	3.28	....	26 98	93
97	Superior Phosphate—H. C. Gates, Brooklyn, O	1.96	10.10	2.62	0.60	22 00	97
98	Sure Crop Phosphate—Bowker Fertilizer Co., Boston, Mass	1.61	12.65	2.87	1.81	26 25	98
99	Am. Dissolved Bone—Bowker Fertilizer Co., Boston, Mass	2.92	11.88	2.42	1.62	30 26	99
100	Bowker's Hill and Drill—Bowker Fertilizer Co., Boston, Mass	4.04	13.67	1.98	1.85	38 41	100
101	Superphosphate with Potash—Bowker Fertilizer Co., Boston, Mass	....	15.91	3 77	1.58	24 20	101
102	Superphosphate—Bowker Fertilizer Co., Boston, Mass	....	18.85	4.60	....	26 06	102
103	Fine Ground Bone—Bowker Fertilizer Co., Boston, Mass	3.57	18.72	....	....	....	103
104	Milson's Potash Fertilizer—Milson Rendering & Fertilizer Co., Buffalo, N. Y	2.81	8.82	2 62	1.35	24 02	104
106	Milson's Buffalo Guano—Milson Rendering & Fertilizer Co., Buffalo, N. Y	3.06	13.03	7.15	1.62	26 60	106
107	Milson's Buffalo Fertilizer, Milson Rendering & Fertilizer Co., Buffalo, N. Y	4.68	8.43	4.41	2.74	32 58	107
108	Soluble Bone Phosphate—Davidge Fertilizer Co., New York	....	10.73	0.70	1.89	19 79	108
110	Ohio Farmer Bone—Western Union Chemical Co., Cleveland, O	3.87	14.44	2.36	0 29	36 57	110
112	Lake Erie Fish Guano—Jarecki Chemical Works, Sandusky, O	1.36	14.82	7.09	0.96	26 65	112
113	Currie's Wheat Grower—The Currie Fertilizer Co., Louisville, Ky	2.55	12.65	3.19	1.04	28 40	113
114	Chicago Bone Meal—Thompson & Edwards, Chicago, Ill	3.83	17.25	11.75	2.29	37 74	114
116	Crop Multiplier—G. F. Bruer Manufacturing Co., St. Louis, Mo	3.53	12.14	1.79	....	31 72	116
118	Animal Guano—Thompson & Edwards, Chicago, Ill	3.14	12.59	5.75	0.79	32 04	118
119	Garden City Superphosphate—N. W. Fertilizer Co., Chicago, Ill	2.97	12.14	3.96	0.48	27 40	119
121	Farmers' Choice Bone Phosphate—I. P. Thomas & Son Co., Philadelphia, Pa	1.70	11.88	2.55	1.97	26 24	121
122	Western Reserve Fertilizer—Jonathan Warner, Mineral Ridge, O	....	trace	trace	0.23	0 30	122
123	Ammoniated Wheat and Corn Phosphate—Crocker Fertilizer and Chemical Co., Buffalo, N. Y	3.06	11.24	1 79	2.04	31 06	123
124	Superphosphate—Jarecki Chemical Works, Sandusky, O	1.11	13.42	5 87	0.86	20 53	124
125	Am. Flour of Bone—The Currie Fertilizer Co., Louisville, Ky	2.00	17 25	7.02	....	32 01	125
126	The Q. C. Bone Phosphate—The Currie Fertilizer Co, Louisville, Ky	2.46	11.83	3.83	....	24 56	126
127	Reliance Dissolved Bone—Walton, Whann & Co., Wilmington Del	....	15.33	3.21	....	21 82	127
128	Am. Dissolved Bone—The Currie Fertilizer Co., Louisville, Ky	1.55	10.60	1.27	2.74	25 82	128
129	National Bone Dust—N. W. Fertilizer Co., Chicago, Ill	2.64	12.39	3.64	....	28 54	129
130	Red Star Ferric Fertilizer—The Star Slaughtering and Phosphate Co., Washington C. H., O	0 09	7.71	6.32	0.04	5 28	130
136	Farmers' Friend Bone Phosphate—M. Hamm & Co., Chillicothe, O	1.11	15.46	6.83	0 23	26 02	136
137	Success Bone Phosphate—T. Carver & Co., Chillicothe, O	1.36	7.03	5.62	0 66	14 05	137
138	Farmers' Pride Bone Phosphate—T. Carver & Co., Chillicothe, O	2.38	12.39	9.45	0.73	24 44	138
139	Ohio Sure Growth—Thompson & Edwards, Chicago, Ills	2.04	16.74	7.41	0.41	77 10	139
140	Critchfield Standard Phosphate—E. P. Critchfield, Howard, O	0.17	18.14	3.70	0 07	26 77	140
141	Acid Phosphate—Sharpless & Carpenter, Philadelphia, Pa	....	17.38	4.09	....	24 23	141
142	No. 1 Bone Phosphate—Sharpless & Carpenter, Philadelphia, Pa	1.96	9.71	2.04	2.16	24 12	142
143	Star Perfection Phosphate—Star Slaughtering and Phosphate Co., Washington C. H., O	2.64	8.94	6.39	0.21	17 19	143
144	Prairie Phosphate—N. W. Fertilizer Co., Chicago, Ills	2.21	14.05	5.49	....	28 14	144
145	Garden City Superphosphate—N. W. Fertilizer Co., Chicago, Ills	2.72	12.78	4.09	0.29	27 13	145
146	Quinn Am. Dissolved Bone—The Quinnpiac Co., New London, Conn	2.55	13.42	2.68	1.41	30 85	146
147	Square Brand Bone and Potash—Bowker Fertilizer Co., Boston, Mass	1.87	12.39	2.81	2.25	27 45	147
151	Currie's Black Diamond Phosphate—The Currie Fertilizer Co., Louisville, Ky	....	11.69	1.53	0.31	18 28	151
153	Farmers' Standard Phosphate—G. Ober & Sons, Baltimore, Md	2.38	10.60	2.30	2.22	26 96	153
154	Dissolved Bone Phosphate—G. Ober & Sons, Baltimore, Md	....	16.99	3.45	....	24 40	154
155	Ohio Dissolved Bone—Piketon Hardware Co., Piketon, O	....	16.74	1.79	....	26 13	155
156	T. & P. Superphosphate—Waring Manufacturing Co., Colora, Md	....	16.67	2.81	....	24 68	156
157	Q. & L. Ammoniated Phosphate—Waring Manufacturing Co., Colora, Md	1.62	14.69	3.83	2.04	28 80	157
158	Fish Am. Superphosphate—Waring Manufacturing Co., Colora, Md	0.85	16.48	3.83	....	26 26	158
160	Yearsley's Soluble Bone and Potash—J. Yearsley, Coatsville Pa	....	16.87	2.43	1.02	26 85	160

TABULATED ANALYSES AND VALUATIONS OF FERTILIZERS, UP TO DECEMBER 31, 1889—Continued.

Record number.	Name of fertilizer and address of manufacturer.	Per cent of ammonia.	Total per cent. of phosphoric acid.	Per cent. of insoluble phosphoric acid.	Per cent. of potash.	Estimated value per ton.	Record number.
162	Farmers' Friend—Read & Co., New York, N. Y	2.29	13.67	1.72	2.53	$33 00	162
163	Lion Brand—Read & Co., New York, N. Y	1.70	11.12	1.92	4.34	28 51	163
164	Our Original Alkaline Bone, Read & Co., New York. N. Y.	....	13.80	1.85	3.59	25 73	164
165	Accidulated Phosphate—New Jersey Chemical Co., Philadelphia, Pa	....	17.63	1.92	....	27 48	165
166	Soluble Bone and Potash—New Jersey Chemical Co., Philadelphia, Pa	....	14.82	1.15	2.22	26 59	166
167	Victor Bone Fertilizer—New Jersey Chemical Co., Philadelphia, Pa	1 62	8.82	1.02	2.41	22 96	167
168	Dissolved Bone Phosphate and Potash—The Baltimore Guano Co., Baltimore, Md	....	14 58	2.17	4.92	28 37	168
169	B. G. Am. Bone Phosphate—The Baltimore Guano Co.. Baltimore, Md	1.79	10.22	3.19	4.24	25 54	169
171	Game Guano—The Baltimore Guano Co., Baltimore Md	2.98	11.63	2.94	2.64	30 70	171
172	High Grade Superphosphate of Bone—D. Blocker & Co., Gettysburg, Pa	1 36	13.16	3 06	1.23	25 16	172
173	Dissolved Bone and Potash—D. Blocker & Co., Gettysburg, Pa	1.11	13.03	1.79	1.98	27 73	173
174	Am. Soluble Bone Phosphate—D. Blocker & Co., Gettysburg, Pa	0.59	12.20	2.68	1.44	21 36	174
175	Keystone Dissolved Bone Phosphate—D. D. Hess & Son, Reading, Pa	0.94	13.32	0.64	....	25 56	175
176	Acid Phosphate—D. D. Hess & Son, Reading, Pa	....	16.80	1.28	....	26 89	176
177	Am. Bone Superphosphate—D. D. Hess & Son, Reading, Pa	2.47	11.50	1.28	1.16	28 95	177
178	G. E. G. Dissolved Bone—Great Eastern Fertilizer Co., Rutland, Vt	....	16.93	2 94	....	24 96	178
180	Homestead Tobacco Grower—Michigan Carbon Works, Detroit, Mich	3.95	11.69	0.90	3.39	38 66	180
181	Erie City Fertilizer—Schaal Bros., Erie, Pa	1.67	9.13	1.73	2.20	22 48	181
184	Special Favorite—Davidge Fertilizer Co., New York	1.79	13.16	1.79	2.04	29 50	184
186	Farmers' Fertilizer—Manly & Miller, Archibald, O	2.47	6.64	3.06	2.08	21 24	186
188	Golden Harvest Superphosphate—James McCallum & Co., Dayton, O	3.40	13.16	4.86	....	31 89	188
189	Am't'd Dissolved Bone—James McCallum & Co., Dayton, O	3.66	12.52	3.70	2.56	35 93	189
191	Bone Phosphate—Christman Rudi Weibach, Archibald, O	1.70	6.51	trace.	0.56	18 26	191
192	Star Bone Phosphate—Star Slaughtering and Phosphate Co., Washington C. H., O	4.70	8 18	2.18	1.79	32 57	192
194	Zell's Economizer—Zell Guano Co., Baltimore Md	1.36	14.44	3.58	1.48	26 98	194
195	Zell's Dissolved Bone Phosphate—Zell Guano Co., Baltimore, Md	....	18.02	3.58	....	25 98	195
196	Calvert Guano—Zell Guano Co., Baltimore, Md	1 02	14 50	3.58	....	28 87	196
197	Ralston's Bone Meal—Northwestern Fertilizer Co., Chicago, Ill	2.89	15.84	7.46	....	32 69	197
198	Am'd Dissolved Bone—Northwestern Fertilizer Co., Chicago, Ill	2.80	11.88	3 08	0.91	28 01	198
199	Dissolved Raw Bone—Northwestern Fertilizer Co, Chicago, Ill	3.06	16 99	2.42	....	38 82	199
201	Acid Phosphate—Northwestern Fertilizer Co, Chicago, Ill	....	18 14	6.40	....	22 52	201
202	Alkaline Acid Phosphate—Northwestern Fertilizer Co., Chicago, Ill	....	16 61	6 26	2.02	22 73	202
203	26 Dollar Phosphate—Northwestern Fertilizer Co., Chicago, Ill	2.38	12.39	3.84	....	25 12	203
204	Am. Bone Superphosphate—Chesapeake Guano Co, Baltimore, Md	1.49	13.29	8 70	1.06	24 82	204
205	Corn and Oats Fertilizer—Chesapeake Guano Co, Baltimore, Md	0.94	12 78	2 82	1.08	23 03	205
206	Desiccated Bone Phosphate—Chesapeake Guano Co., Baltimore, Md	....	15.78	1.60	....	24 75	206
208	Improved Bone—Western Union Chemical Co., Cleveland, O	3.49	20.57	0.36	....	40 98	208
209	Rotted Bones—Western Union Chemical Co., Cleveland, O	....	14.57	2.50	....	21 52	209

211	Competition—M. Hamm & Co., Chillicothe, O	....	12.78	1.66	0.26	19 90	211
214	Salem Special Manure—Vaughn, Bonsall & Co., Salem, O	5.02	28.88	13.80	....	50 24	214
215	Globe Bone Phosphate—Springfield Fertilizer Co., Springfield, O	2.81	16.10	3.19	1.62	36 02	215
217	Soluble Bone Phosphate—Springfield Fertilizer Co., Springfield, O	1.79	10.60	1.91	3.43	26 79	217
218	Tobacco and Vegetable Superphosphate—Springfield Fertilizer Co., Springfield, O	4.93	8.56	0.89	6.79	40 96	218
219	Atlas Bone Phosphate—Springfield Fertilizer Co., Springfield, O	2.64	14.57	4.21	3.88	34 36	219
220	Rasin's Acid Phosphate—Rasin Fertilizer Co., Baltimore, Md	0.17	16.61	2.04	....	26 24	220
221	Soluble Sea Island Guano—Rasin Fertilizer Co., Baltimore, Md	2.13	11.50	1.91	....	25 15	221
222	Dissolved Bone—Rasin Fertilizer Co., Baltimore, Md	2.72	12.27	1 40	....	29 38	222
224	Baugh's Double Eagle Phosphate—Baugh & Sons, Philadelphia, Pa	2.64	11.11	2 17	....	26 10	224
226	Potato, Hop and Tobacco Phosphate—Crocker Fertilizer & Chemical Co., Buffalo, N. Y	2.55	11.24	0.96	4.55	33 47	226
227	New Rival Am. Superphosphate—Crocker Fertilizer & Chemical Co., Buffalo, N. Y	1.79	10.99	1.08	2.51	27 34	227
230	Detrick's Am. Bone Superphosphate—Bradley Fertilizer Co., Boston, Mass	1.62	14.57	2.17	0.65	28 96	230
231	Dissolved Sc. Bone—W. S. Powell, Baltimore, Md	....	15.59	0.41	....	25 94	231
232	Red Bag Fertilizer—W. S. Powell, Baltimore, Md	1.45	12 27	3.32	1.08	23 46	332
233	Tip-top Bone Fertilizer—W. S. Powell, Baltimore, Md	2.38	11.63	3.58	1.62	22 27	233
234	Bone and Potash Fertilizer—W. S. Powell, Baltimore, Md	....	14.05	0.51	1.17	24 74	234
235	Pride—H. S. Roberts & Co., Westminster, Mo	2.38	11.12	2.55	2.56	27 96	235
236	Big Gun—H. S. Roberts & Co., Westminster, Mo	2.04	11.36	2.55	2.08	26 43	236
237	Governor—H. S. Roberts & Co., Westminster, Mo	1.19	9.71	1.40	2.54	22 51	237
238	Anchor Bone—H. S. Roberts & Co., Westminster, Mo	....	15.21	1.53	....	23 87	238
240	Zell's Am. Bone Superphosphate—Zell's Guano Co., Baltimore, Md	2.13	11.50	2.55	1.75	26 59	240
241	Pure Dissolved Bone with Potash—Walker, Stratman & Co., Pittsburgh, Pa	1.96	9 07	2.30	3.53	24 47	241
243	Bone and Meat Fertilizer—Walker, Stratman & Co., Pittsburgh, Pa	4.97	12.14	9.20	....	33 08	243
244	Baltimore Dissolved Bone—Slingluff & Co., Baltimore, Md	1 06	14.69	1.28	....	27 31	244
245	Special Tobacco—Chappell Chemical & Fertilizer Co., Baltimore, Md	2.21	10 73	1.53	4.01	29 86	245
246	Special Corn and Oats—Chappell Chemical & Fertilizer Co., Baltimore, Md	....	12.78	1.28	2.74	23 62	246
247	Farmers' Reliance Am Superphosphate—Chappell Chemical & Fertilizer Co., Baltimore, Md	1.19	8.30	1.92	2.20	19 00	247
248	Dissolved Raw Bone—Chappell Chemical & Fertilizer Co., Baltimore, Md	2.52	13.67	2.94	....	29 11	248
249	Special Wheat and Grass Fertilizer—Chappell Chemical & Fertilizer Co., Baltimore, Md	1.53	10.09	1.40	2.87	24 87	249
250	Royal Bone Phosphate—Williams, Clark & Co., New York	1.66	9.07	0.78	2.35	23 76	250
251	Universal Am'd Dissolved Bone—Williams, Clark & Co., New York	2.21	9.97	0.51	2.47	27 89	251
552	Prolific Crop Producer—Williams, Clark & Co., New York	1.45	7.54	1.53	1.17	17 86	252
253	Baker's Dissolved Bone Phosphate—Chemical Co. of Canton, Baltimore, Md	....	15.59	2.04	....	23 86	253
254	Soluble Bone and Potash—Chemical Co. of Canton, Baltimore, Md	....	15.59	3.96	2.76	24 94	254
255	Complete Fertilizer—A. B. Mayer Mfg. Co., St. Louis, Mo	3 36	9.20	4.53	0.60	26 02	255
256	S. C. & C. Guano—Carib Guano Co., Baltimore, Md	0.26	19.30	14.44	0.75	16 01	256
257	Potato and Hop Phosphate—Milson Rendering & Fertilizer Co., Buffalo, N. Y	3.15	10.73	3.13	6.13	34 11	257
258	Vegetable Bone Fertilizer—Milson Rendering & Fertilizer Co., Buffalo, N. Y	5.98	6.52	0.76	7.72	42 82	258
259	Farmers' Alkaline Bone—Lorenz & Rittler, Baltimore, Md	....	13.80	0.64	4.49	28 44	259
261	Normal Bone Phosphate—I. P. Thomas & Son Co., Philadelphia, Pa	1.53	12.27	3.06	1.89	25 15	261
262	Potato Manure—I. P. Thomas & Son Co., Philadelphia, Pa	2.30	12.14	4.21	7.95	34 24	262
269	....	1.19	9.71	3.32	2.62	20 12	269
28a	Gilead Phosphate—Cincinnati Desiccating Co., Cincinnati, O	3.82	10.48	2.55	2.10	33 28	28a
97a	Superior Phosphate—H. C. Gates, Brooklyn, O	2.98	10.80	5.18	2.30	26 93	97a

TABULATED ANALYSES AND VALUATIONS OF FERTILIZERS, UP TO DECEMBER 31, 1889.

[ISSUED BY THE OHIO STATE BOARD OF AGRICULTURE, JANUARY 15, 1890.]

The analysis are by Prof. N. W. Lord, Ohio State University, Columbus, Chemist of the Board of Agriculture. The samples were selected by the Secretary of the Board, in accordance with the act of March 16, 1881. All samples given are verified by oath on file in this office. The valuations are by the Secretary, and are based on the average commercial value of the ingredients in Ohio, as sold in fertilizers, viz., ammonia, 19 cents per pound; insoluble phosphoric acid, "fine" bone, 5 cents; in "medium" bone, 4 cents; coarse bone, 3 cents.

TABLE II.—Bone and "untreated" organic matter. See, also, Table I, for Superphosphates.]

Record number.	Name of fertilizer, and address of manufacturer.	Per cent. of ammonia	Total phosphoric acid.	Estimated value per ton in dollars and cents.	Record number.
2	Homestead Desiccated Bone—Michigan Carbon Works, Detroit, Mich.	3.23	26.92	$38 38	2
3	Homestead Raw Bone Meal and Potash—Michigan Carbon Works, Detroit, Mich	2.89	15.14	*29 26	3
5	Banner Bone Flour—Michigan Carbon Works, Detroit, Mich	4.19	19.04	34 12	5
6	Salem Bone Dust—Vaughn, Bonsall & Co., Salem, O	5.58	21.30	41 18	6
11	Peerless Bone Dust—Canton Fertilizer Co., Canton, O.	4.75	22.23	38 55	11
14	Pure Ground Bone—Great Eastern Fertilizer Co., New York	5.36	22.81	40 86	14
31	Horseshoe Brand Fine Raw Bone—Northwestern Fertilizer Co., Chicago, Ills.	4.67	23.64	40 63	31
37	Akron Ground Bone—Dick & Miles, Akron, O.	3.06	22.43	33 16	37
43	Pure Raw Bone Meal—Herrick, Harris & Co., Cleveland, O.	4.86	22.96	40 00	43
47	Pure Ground Bone—Crocker Fertilizer and Chemical Co., Buffalo, N. Y.	5.28	22.90	41 40	47
48	Pure Raw Bone Meal—Cincinnati Desiccating Co., Cincinnati, O.	5.15	24.24	42 12	48
52	Pure Fine Bone Meal—Walker, Stratman & Co., Pittsburgh, Pa.	2.30	23.10	31 70	52
55	Square Bone—Cleveland Dryer Co., Cleveland, O	3.15	15.56	26 57	55
58	Pure Bone Meal—Walker, Stratman & Co., Pittsburgh, Pa	2.55	22.84	32 40	58
59	Tiger Bone Meal—Western Union Chemical Co., Cleveland, O.	4.15	24.60	38 59	59
75	Raw Bone Meal—Cincinnati Desiccating Co., Cincinnati, O.	4.93	23.00	40 17	75
79	Pure Bone Dust—Newburg Fertilizer Co., Newburg, O.	4.56	24.26	39 75	79
90	Superior Bone—Cleveland Dryer Co., Cleveland, O.	5.23	22.70	41 07	90
94	Valley Bone—J. L. & H. Stadler, Palmer, O	4.31	22.92	38 56	94
95	Raw Knuckle Bone Meal—H. C. Gates, Brooklyn, O.	5.15	23.06	41 29	95
96	Raw Bone Meal—H. C. Gates, Brooklyn, O.	4.56	22.94	38 99	96
105	Pure Bone Meal—Milson Rendering and Fertilizing Co., Buffalo, N. Y.	5.01	22.62	38 95	105
109	Tiger Bone Meal—Western Union Chemical Co., Cleveland, O.	4.42	22.62	39 42	109
115	Pure Bone Meal—Thompson & Edwards, Chicago, Ills	2.29	19.68	27 91	115

5* B2 O.EX.ST.

117	*Pure Raw Bone Meal—Geo. F. Bruner Manufacturing Co., St. Louis, Mo.	4.38	23.51	40 10	117
120	Fine Raw Bone—Northwestern Fertilizer Co., Chicago, Ills.	4.16	21.85	37 26	120
131	Pure Ground Raw Bone—Thompson & Edwards, Chicago, Ills	4.34	21.53	36 00	131
132	Pure Fine Ground Bone—Thompson & Edwards, Chicago, Ills	2.55	21.[illegible]2	30 80	132
133	Pure Bone Meal—M. Hamm & Co., Chillicothe, O.	4.55	23.38	39 27	133
134	Pure Bone Meal—P. B. Mathiason & Co., St. Louis, Mo	4.34	23.64	39 70	134
135	Excelsior Raw Bone—T. Carver & Co., Chillicothe, O.	4.34	21.34	36 46	135
152	Akron Ground Bone—Dick & Miles, Akron, O	2.55	27.86	36 15	152
159	Iridescent Raw Bone Meal—P. B Mathiason & Co., St. Louis, Mo.	5.02	22.75	41 20	159
161	Fine Ground Bone—Cincinnati Desiccating Co., Cincinnati, O.	4.76	20.96	37 53	161
182	Urich's Pure Bone—Elias Urich, Uhrichsville, O.	4.93	23.89	41 71	182
185	Raw Bone Meal—Walton, Whann & Co., Wilmington, Del.	4.21	23.77	39 63	185
190	Superior Ground Bone—James McCallum & Co., Dayton, O	4.50	22.36	38 66	190
193	Star Bone Meal—Star Slaughtering and Phosphate Co., Washington C. H., O.	3.66	23.56	36 52	193
200	Pure Ground Bone—Northwestern Fertilizer Co., Chicago, Ills.	1.87	27.73	34 56	200
207	Pure Ground Soluble Bone Meal—H. C. Gates, Brooklyn, O	2.81	25.60	35 36	207
210	Western Pure Bone Meal—R. J. Wilhelm, Portsmouth, O.	2.98	27.86	37 95	210
216	Pure Ground Bone—Springfield Fertilizer Co., Springfield, O.	4.85	22.23	38 36	216
223	Baugh's Raw Bone Meal—Baugh & Sons, Philadelphia, Pa.	4.72	21.98	39 57	223
225	Dorst Bone Meal—John Dorst, Pomeroy, O	5.48	21.72	40 59	225
228	Pure Raw Bone—E. Raugh & Sons, Indianapolis, Ind.	4.42	23.45	40 19	228
239	Pure Bone Meal—A. B. Mayer Manufacturing Co., St. Louis, Mo.	4.76	21.98	38 93	239
242	Pure Raw Bone—Walker, Stratman & Co., Pittsburgh, Pa.	4.76	22.49	39 59	242

*Includes 2.70 per cent. potash.

In addition to the analyses given above, thirty-five other brands have been licensed, but have not yet been analyzed.

COMMERCIAL VALUATIONS OF FERTILIZERS.

BY PROF. N. W. LORD, CHEMIST OF THE OHIO STATE BOARD OF AGRICULTURE.

There is still some misunderstanding as to the commercial valuation attached to the various ingredients of the several brands of fertilizers printed in the tables in this report. To make the matter as clear as possible, a few words may be said in explanation.

The main fact to be always remembered is that the value given to the different brands do not necessarily or even usually express their fertilizing value. Or, in other words, a fertilizer which shows the highest valuation, is not therefore a better fertilizer for any particular locality than one which shows a much less one.

Now what, then, does this commercial value express? To answer this it must be understood that fertilizers are mixtures of certain materials, each of which is necessary to the soil, but of which some are needed on certain soil in greater proportions than others. Thus, some soils and some crops need phosphoric acid mostly, some need potash, and some need ammonia. The needs of a soil the farmer can determine by experiment, and his fertilizer should be selected to meet the case, that is, whichever element is most needed should be the one most prominent in the fertilizer, and with this part of the selection the commercial valuation has nothing to do at all.

Now, bearing this in mind, we can understand the real application of the commercial valuation, which is this: These several ingredients, ammonia, phosphoric acid and potash have very different costs; if you want to buy a pound of ammonia you must pay about 19 cents for it, (at retail, in small markets); if you want a pound of available phosphoric acid, you must pay about 8½ cents for it, and in this same way about 6½ cents for a pound of potash. Now, when you buy these things mixed together you pay for this mixture what the various ingredients cost separately, and it is this that is printed as the commercial valuation. For example: A certain fertilizer has, say 5 % ammonia, 10 % available phosphoric acid, and 3 % of potash; that means that in one ton, or 2,000 lbs. of these articles, there are as follows: 100 pounds of ammonia, 200 lbs. of available phosphoric acid, and 60 pounds of potash; the rest being dirt, rock, lime, organic matter, etc., necessary to hold this material. Now to make that fertilizer you would have to buy—

100 pounds of ammonia, at 19 cents	$19 00
200 pounds of phosphoric acid, at 8½ cents	17 00
60 pounds potash, at 6½ cents	3 90
Total	$29 90

Or this fertilizer would cost $29.90 to make, if you purchased the ingredients at retail and mixed them. In other words, the valuations simply show that this fertilizer is "full weight" and furnishes its ingredients at their fair market value, but do *not* show that the high-priced fertilizer is the one a particular farm demands.

Hence, if a farmer pays the valuation for a fertilizer, he gets his money's worth *commercially*. Whether he buys what he needs or not, depends upon whether he has selected the kind of fertilizer his farm requires.

Ammonia being the most expensive ingredient by far, that enters into fertilizers, brands high in that element always show the highest valuation, and hence this ingredient, if put where it is not needed, will mean the greatest waste of money, while the cheaper phosphates can give just as much value for the money as the high-priced ammonia fertilizers.

The careful consideration of these facts will show that the *composition*, as given in the tables, is a more important thing than the values; that these latter merely serve to show that the price of the article is fairly related to its cost of production.

The next number of the Bulletin of the Ohio Experiment Station will be published in April, and will be devoted to EXPERIMENTS WITH CORN AND OATS.